USAFETAC/PR--92/005

# ASPAM

## ATMOSPHERIC SLANT PATH ANALYSIS MODEL
## Statistical Paired Differences Pilot Study for Sample Size Determination

by

Capt Thomas H. Elio
Mr Charles R. Coffin
Major Lauraleen O'Connor

**NOVEMBER 1992**



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**ENVIRONMENTAL TECHNICAL APPLICATIONS CENTER (USAFETAC)**
**Scott Air Force Base, Illinois, 62225-5116**

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Walt F. Miller

WALTER F. MILLER
Chief, Simulations and Techniques Branch

FOR THE COMMANDER

Walter S. Burgmann

WALTER S. BURGMANN
Scientific and Technical Information
Program Manager
*24 November 1992*

## REPORT DOCUMENTATION PAGE

2. Report Date: November 1992

3. Report Type: Project Report

4. Title: *ASPAM (Atmospheric Slant Path Analysis Model) Statistical Paired Differences Pilot Study for Sample Size Determination*

6. Authors: Capt Thomas H. Elio, Mr Charles R. Coffin, and Maj Lauraleen O'Connor

7. Performing Organization Names and Address: United States Air Force Environmental Technical Applications Center (SYT), Scott AFB, IL 62225-5116

8. Performing Organization Report Number: USAFETAC/PR--92/005

12. Distribution/Availability Statement: Approved for public release; distribution is unlimited.

13. Abstract: Describes methodology and results of a pilot study intended to determine the required sample size for a statistically significant seasonal study of the differences between ground truth (represented by upper-air soundings) and (1) Atmospheric Slant Path Analysis Model (ASPAM) optimum interpolation vertical profiles (OIVPs) and (2) alternate vertical profiles. This study builds on earlier ASPAM studies, incorporating lessons learned and user feedback. It found that a sample size of 50 observations was enough to determine if the differences between ground truth (upper-air soundings) and ASPAM vertical profiles were significant at the customer's confidence level.

14. Subject Terms: CLIMATOLOGY, ATMOSPHERE, PROFILES, UPPER-AIR, TEMPERATURE, MOISTURE, VERTICAL SOUNDINGS, SAMPLING, STATISTICS, STATISTICAL SAMPLING, SAMPLE SIZE, COMPUTERS, COMPUTING, COMPUTER MODELING,

15. Number of Pages: 42

17. Security Classification of Report: Unclassified

18. Security Classification of this Page: Unclassified

19. Security Classification of Abstract: Unclassified

20. Limitation of Abstract: UL

**Standard Form 298**

## PREFACE

This report documents a USAFETAC pilot study done for the Air Weather Service Special Projects Division (AWS/DOS). The study was initiated to determine the required sample size for a statistically significant seasonal study of the differences between ground truth (represented by upper-air soundings) and (1) Atmospheric Slant Path Analysis Model (ASPAM) optimum interpolation vertical profiles (OIVPs) and (2) alternate vertical profiles.

Specifically, AWS/DOS tasked USAFETAC to conduct a baseline ASPAM study that would determine the spatial, seasonal, and temporal statistical variability of the temperature and moisture optimum interpolation vertical profiles. The study only addresses the statistical accuracies of USAFETAC's version of the model.

In August 1990, USAFETAC's Special Projects Section (DOS) evaluated 112 cases from various climatic regimes, seasons, and time of day. This study led to the discovery of several minor ASPAM software problems. Other studies by the AWS Technology Division (AWS/XTX) postulated that HIRAS smoothing and/or limitations in the space-time resolution of observations might degrade OIVP performance.

This study builds on earlier ASPAM studies, incorporating lessons learned and user feedback. It found that a sample size of 50 observations was enough to determine if the differences between ground truth (upper-air soundings) and ASPAM vertical profiles were significant at the customer-stated confidence level.

The authors wish to thank those who worked closely with us on this project. They include Major Harold Massie (AWS/DOS) for providing test guidance; Capt Jeff McCoy for McIDAS support; the USAFETAC Point Analysis Team (Mr Mark Surmeier, Capts Greg Reding and David Martens, MSgt Richard Boyle, TSgts Heidi Tryon, Joan Bergmann and Catherine Bird), the USAFETAC Database Administration Section (TSgt Dennis Murphy and Mrs Nancy Toon); AFGWC's special projects people (Capt Farrar and Capt Lunn); the AFGWC database administrator (Capt Hanser); and the AFGWC HIRAS maintenance programmer (Capt Carlson). Finally, thanks to Mr Tom Kotz, USAFETAC/OL-A, for providing the data necessary for a thorough statistical evaluation.

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# 1. INTRODUCTION

**1.1 ASPAM Background.** AFGWC and USAFETAC provide detailed vertical atmospheric profiles to specified military agencies and Department of Defense (DoD) contractors. These profiles, called "point analyses," provide customers with the meteorological data they need to make decisions with respect to atmospheric conditions at a specific place and time. The computer model used to produce these point analyses (or PAs) is called the "Atmospheric Slant Path Analysis Model," or "ASPAM." The model was recently enhanced to accommodate new or improved meteorological databases and improved techniques, such as:

- The New Upper Air Validator (NUAV).

- The Real-time Nephanalysis (RTNEPH) cloud database.

- Finer resolution data fields in the High-Resolution Analysis System (HIRAS).

- More sophisticated mathematical techniques, such as statistical optimum interpolation, which weights various observations not only by their distance from the point of interest, but by the statistical accuracy of the different types of data used.

- Alternate vertical profiles, which provide temperature profiles one standard deviation warmer and moisture profiles one standard deviation drier than the "best" temperature and moisture profiles.

In August 1990, USAFETAC's Special Projects Section (DOS) evaluated 112 ASPAM vertical profiles from various climatic regimes, seasons, and time of day. The evaluation led to the discovery of several minor software problems. Although there were too few samples used to achieve statistical significance, the study provided a better understanding of the model's strengths and weaknesses, which included:

- The optimum interpolation vertical profile (OIVP) scheme did not use (or may have misused) RAOB data.

- OIVP moisture errors can (at times) significantly exceed RAOB instrument errors.

- The use of an eighth-mesh terrain database contributed to large density errors in areas of complex terrain.

Other studies by the AWS Technology Division (XTX) postulated that HIRAS smoothing, and/or limitations in the space-time resolution of observations, might also degrade OIVP performance.

**1.2 Why the Study Was Conducted.** As requested by the Air Weather Service Directorate of Operations, Special Projects Division (AWS/DOS), USAFETAC evaluated the Atmospheric Slant Path Analysis Model (ASPAM) to determine the seasonal statistical variance of the temperature/moisture optimum interpolation vertical profiles (OIVPs). This study builds upon several earlier ASPAM studies, incorporating lessons learned and user feedback. The study had two main purposes:

- Satisfy point analysis customer requirements for a statistically significant baseline analysis of the ASPAM temperature and moisture OIVP and alternate profiles by climatic regions, season and atmospheric level.

- Provide data for use in determining if modifications for the ASPAM code were required.

**1.3 How the Study was Conducted.** USAFETAC measured differences from the surface to 100,000 feet for the polar/arctic, mid-latitude, and moist tropical climatic regions. The study describes sample size calculation for ASPAM differences from ground-truth.

Radiosonde observations (RAOBs), used as ground truth, were denied from the Air Force Global Weather Central's (AFGWC's) parallel High Resolution Analysis System (HIRAS) database. ASPAM profiles were subsequently analyzed at the denied RAOB locations, then compared with those RAOBs.

Finally, analysts determined the number of observations needed for a statistically valid variance study of ASPAM temperature and moisture accuracy.

## 2. PILOT STUDY STATISTICS

**2.1 Analysis Flow.** The pilot study consisted of separate sample size calculations for each region (arctic, mid-latitude, and moist tropics) of the mean error, standard deviation, examined differences between ASPAM's RAOBVP analysis (ground truth) and OIVP temperature and moisture profiles.

The mean and standard deviation of the differences for temperature and moisture were calculated from the surface to 100,000 feet above ground level in 1,000-foot increments to 10,000 feet and every 5,000 feet thereafter. The sample sizes were calculated using these results.

**2.2 Statistical Sampling.** A statistical sampling plan constitutes three distinct parts, all accomplished using strict statistical techniques:

- Calculation of sample size using sample errors.
- Selection of the sample.
- Evaluation of the results.

Sampling error (or " precision") is how closely the result from a sample duplicates the result that can be obtained from the complete population (Hansen et al., 1953). Another way of looking at precision is how close the mean of randomly selected samples are to each other. Usually, the precision is stated as a value added to and subtracted from the sample result. The population's characteristics are expected to lie somewhere between these limits. It's possible to estimate the sampling error that will result from the use of a particular sample size. If the number of items from which to choose is limited, choosing more items will result in less risk than in using an estimate made from a smaller sample drawn at random. As the sample size becomes larger, the sample estimate differs less and less from the expected value. It is necessary to determine a degree of assurance that the sample selection is within the range stated.

This assurance is called the "confidence level." If a large number of samples are chosen from a given field (population), they will tend to cluster around a more realistic value of the field. Some of the samples, however, will tend to be extreme and lie outside the limits of this cluster. By statistical methods, it is possible to measure the percentage of time a sample of a given size would result in a condition that is within the stated range. The confidence level is usually expressed as a percentage; values of 95%, 99% and 99.9% reflect very high levels of assurance and meet most requirements.

It can be shown that, for a particular sample size, the wider the margin of precision, the more assurance (or confidence) the sample will fall within it. Conversely, the narrower the margin, the smaller the degree of assurance. Therefore, the precision or confidence level, or both, can be increased by increasing the sample size. Our goal in this study was to determine the sample size that would result in the desired level of assurance.

Confidence intervals can also provide a test of significance. If zero is within the confidence interval, then we say that the population mean difference is statistically equal to zero. If zero is *outside* the confidence intervals, then we can say that the population mean difference is statistically *not* equal to zero (Law and Kelton, 1991). That is, if a sample mean

difference is statistically equal to zero, then the same is implied for the entire population. For this study, a zero mean difference implies the RAOBVP and OIVP parameter values are not statistically different; thus, the OIVP approximates the ground truth RAOBVP reasonably well.

Confidence intervals are based on random sample means and standard errors. The random sample mean is used to measure a central value in the population of temperature or humidity differences. The sample standard deviation measures the scatter or spread in a series of differences around the sample mean. The standard error is the standard deviation of a distribution of random sample means; it measures the spread of a series of random sample means. Standard errors are used to make inferences about the likelihood that the population mean difference lies within the specified interval or range of differences.

The greatest advantage of using a statistical technique to decide on a sampling plan is its ability to measure the reliability and degree of assurance that can be placed on the results. The second most important advantage of statistical sampling is the assurance that the test will objectively bring to light a reasonable cross-section of the field being examined. If the sample is selected according to proper statistical standards, results are justified by using the statistical tables appropriate for the distribution (Hill, Roth, and Arkin, 1979).

In many practical sampling problems, we can assume the values in a dataset are a sample from a normal distribution since large classes of distributions approximate the normal distribution. This fact has great practical importance since it is relatively easy mathematically to work with the normal distribution. Some results may hold well enough for practical applications when samples come from non-normal populations.

Even when the distribution of a population is far from normal, the sampling distribution of the mean approaches the normal distribution as the sample size increases (i.e., as it approaches infinity).

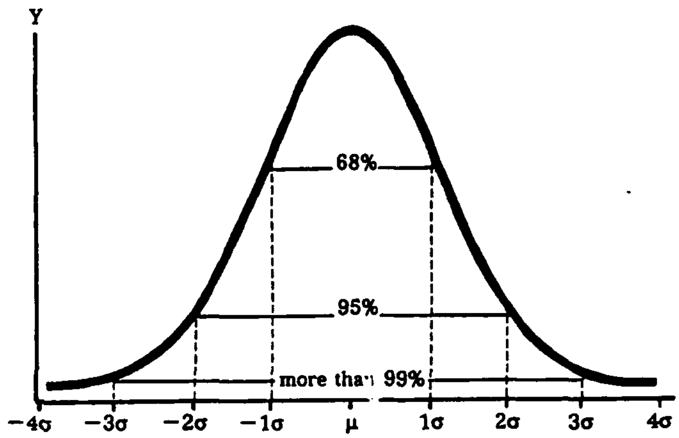


**Figure 1. The Normal Distribution and the Empirical Rule from Schlotzhauer and Littel, 1987.**

Although we cannot know the **exact value** of the error of the estimate of the mean, from the empirical rule for the normal distribution shown in Figure 1 we can say:

- 68% of the values are within one standard deviation of the mean.
- 95% of the values are within two standard deviations of the mean.
- More than 99% of the values are within three standard deviations of the mean (Schlotzhauer and Littel, 1987).

Skewness and kurtosis values are known as "shape" statistics and can be used as measures of departure from normality. "Skewness" means lack of data symmetry

about the mean. "Kurtosis" describes the heaviness of the tails of a distribution.

Positive skewness values indicate that the principal part of the distribution is concentrated on the *left* side of the distribution mean, with a longer tail to the right. Negative skewness occurs when the principal part of a distribution is concentrated on the *right* side of the distribution mean, with a longer tail to the left. When the absolute value of skewness is greater than 1.0, the distribution is highly skewed; when it is between 0.5 and 1.0, the distribution is moderately skewed, and when it is between 0.0 and 0.5, the distribution is nearly symmetric. Skewness values can be useful in determining the type of distribution. A normal distribution has a skewness value of about zero.

Extremely non-normal distributions may have large positive or negative kurtosis values, while nearly normal distributions have kurtosis values close to zero. Kurtosis is positive if the tails are *heavier* than for a normal distribution and negative if the tails are *lighter* than for a normal distribution.

**2.3 Population and Sample Size.** To determine the sample size, the behavior of the data must be summarized by determining the values of the variables that lie near the middle of a frequency distribution. Three measures of central tendency (means, medians, and modes) are commonly used to summarize statistical information. The mean is obtained by the addition of all the observations in a sample and division by the number of cases in the sample. The mean is defined as

$$\bar{X} = \frac{\sum_{i=1}^{n} x_i}{n} \qquad (1)$$

where $\bar{X}$ is the mean, $x_i$ the number of individual observations, and $n$ is the total sample size. The mean doesn't always constitute the "typical" value for some meteorological elements. For example, a mean temperature is more representative than mean daily rainfall since rainfall has a greater tendency for extreme occurrences over short periods of time.

The mode, defined as the most probable value of a variable, is not influenced by extremes at all.

The median, the halfway point in a frequency distribution, is influenced by the number of observations, but not by the value of extreme members.

Once the mean is determined, the degree of variability is calculated using the standard deviation. The standard deviation

$$s = \sqrt{\frac{\sum x^2}{n} - (\bar{x})^2} \qquad (2)$$

places emphasis on large deviations from the mean (Panofsky and Brier, 1968).

A *t*-test can be used to determine the departure of a sample mean ($\bar{X}$) from the true mean, $\mu$. The student-*t* value can be computed by the following (Snedecor and Cochran, 1989):

$$t = \frac{(\bar{X} - \mu)}{s} \qquad (3)$$

where $\bar{X}$ is the sample mean $n$ is the sample size, and $s$ is the standard deviation of the sample.

The confidence intervals can be used to assess the accuracy of the computed sample mean as an estimate of the population mean. The confidence interval for the true

mean difference of paired observations (between RAOBVP and OIVP values, for this study) is given by Snedecor and Cochran, 1989:

$$\bar{d} \pm ts_{\bar{d}} \qquad (4)$$

where $d$ is the sample mean difference, $n$ is the sample size, $t$ is the $t$-test table value, and $s_{\bar{d}}$ is the standard deviation of the differences divided by the square root of the sample size.

The 90%, 95%, and 99% confidence intervals for paired observations in this study were estimated using the normal distribution and Chebyshev's inequality. The normal approximation is usually used when the sample size is greater than 30; however, even if the population is not normally distributed, the central limit theorem states that the sampling distribution of the mean approaches a normal distribution when the random sample size is increased; that is, as the sample size ($n$) approaches infinity. Chebyshev's inequality can also be used to determine confidence limits of the population mean; it is very conservative and can be applied to any type of distribution.

The skewness and kurtosis values given can be used to determine an adjusted $t$ value in defining the confidence interval. Although skewness and kurtosis computations should only be applied to larger samples, they can also be informative in small samples.

A 95% confidence interval for an extremely large population based on the normal distribution (or Chebyshev's inequality for a non-normal distribution) means that we are 95% confident that the random interval will be chosen so that it happens to contain the true population mean difference. The range of the confidence interval reflects sample size. Although large samples decrease the size of the confidence interval, a small sample might also provide adequate information. According to Arkin (1974) and Hansen, Hurwitz, and Madow (1953), the standard deviation can be determined from a random sample of 50 observations. Hansen, et al. (1953) states that if a simple random sample is drawn from a population that is approximated by the normal distribution, then 50 observations are enough to yield a reasonably reliable estimate of the standard error of a mean.

**2.4 Statistical Approach.** Two approaches for calculating the sample size were considered for the ASPAM pilot study:

The first, the simple random sample design, considered the mean standard deviation and customer accuracy requirements. The ratio between customer accuracy requirements, also referred to as sampling error (e.g., temperature accurate to 2°, 4°, and 6° C), and the standard deviation was found. The ratio was used with the 99, 95, and 90 percent confidence limits to obtain the estimated sample size for the population mean differences based on winter 1992 data. For example:

$$SE = t\left(\frac{s}{\sqrt{n}}\right)\sqrt{1 - \frac{n}{N}} \qquad (5)$$

where $SE$ is the sampling error (or customer defined accuracy), $t$ is the Student's t-test statistic value at a given confidence level, $s$ is an approximation of the standard deviation for the population of the paired differences, $n$ is the required sample size, and $N$ is the population size for each stratum (region). As given by Arkin (1974), we can calculate the desired sample size by solving for sample size $n$:

$$n = \frac{t^2}{R^2 + \frac{t^2}{N}} = \frac{1}{\frac{R^2}{t^2} + \frac{1}{N}} \quad (6)$$

where

$$R = \frac{SE}{\sigma} \quad (7)$$

The table shows how the sample size varies with the ratio ($R$) and the confidence levels.

| Sample n | R | N | t | Confidence Level |
|---|---|---|---|---|
| 9090 | 0.02 | 20,000 | ± 2.58 | 99% |
| 6489 | 0.02 | 20,000 | ± 1.96 | 95% |
| 228 | 0.17 | 20,000 | ± 2.58 | 99% |
| 133 | 0.17 | 20,000 | ± 1.96 | 95% |

The second approach was a simple random sample design that considered the standard deviation and sample mean at different confidence levels. The value is calculated

$$\epsilon\mu = t\left(\frac{s}{\sqrt{n}}\right)\sqrt{1-\frac{n}{N}} \quad (8)$$

whereas $N$, $n$, $t$, $s$ are as previously defined, $\epsilon$ is the value set by the investigator; that is, the sample mean estimate ($\bar{X}$) should not differ from the unknown population mean ($\mu$) by more than $\epsilon\mu$. The product ($\epsilon\mu$) is essentially the sampling error stated in our first approach, but expressed in terms of $X$-$\mu$, called "sampling error" or "precision," which is the difference between a "sample" result and the result from a 100% check (the whole population). Solving for $n$ gives

$$n = \frac{\left(\frac{ts}{\epsilon\mu}\right)^2}{\left[1 + 1/N\left(\frac{ts}{\epsilon\mu}\right)^2\right]} \quad (9)$$

As a first approximation we can estimate the sample size using

$$n_o = \left(\frac{ts}{\epsilon\mu}\right)^2 \quad (10)$$

where $n_o$ is the sample size estimate. If $n_o/n$ is appreciable (not negligible) we compute

$$n = \frac{n_o}{1 + \left(\frac{n_o}{N}\right)} \quad (11)$$

For example, for the following conditions, and keeping within a 10% sampling error:

Pilot sample mean ($X$) . . . 3.50
Population size, ($N$) . . . . 2,500
Pilot sample size . . . . . . . . . . 20
Standard Deviation ($s$) . . . . 0.7
Epsilon ($\epsilon$) . . . . . . . . . . . . 0.10
99.73% Confidence level ($t$)± 3.00

The sample size estimate is:

$$n_o = \frac{(3)^2(.7)^2}{(.1)^2(3.5)^2} = \frac{(9)(.49)}{(.01)(12.25)} = \frac{4.41}{0.1225} = 36 \quad (12)$$

Then, solving for $n$

$$n = \frac{36}{1 + \frac{36}{2500}} = \frac{36}{1 + 0.0144} = 35.48 \quad (13)$$

In other words, given our example conditions, a sample size of 36 is needed to have a statistically significant test.

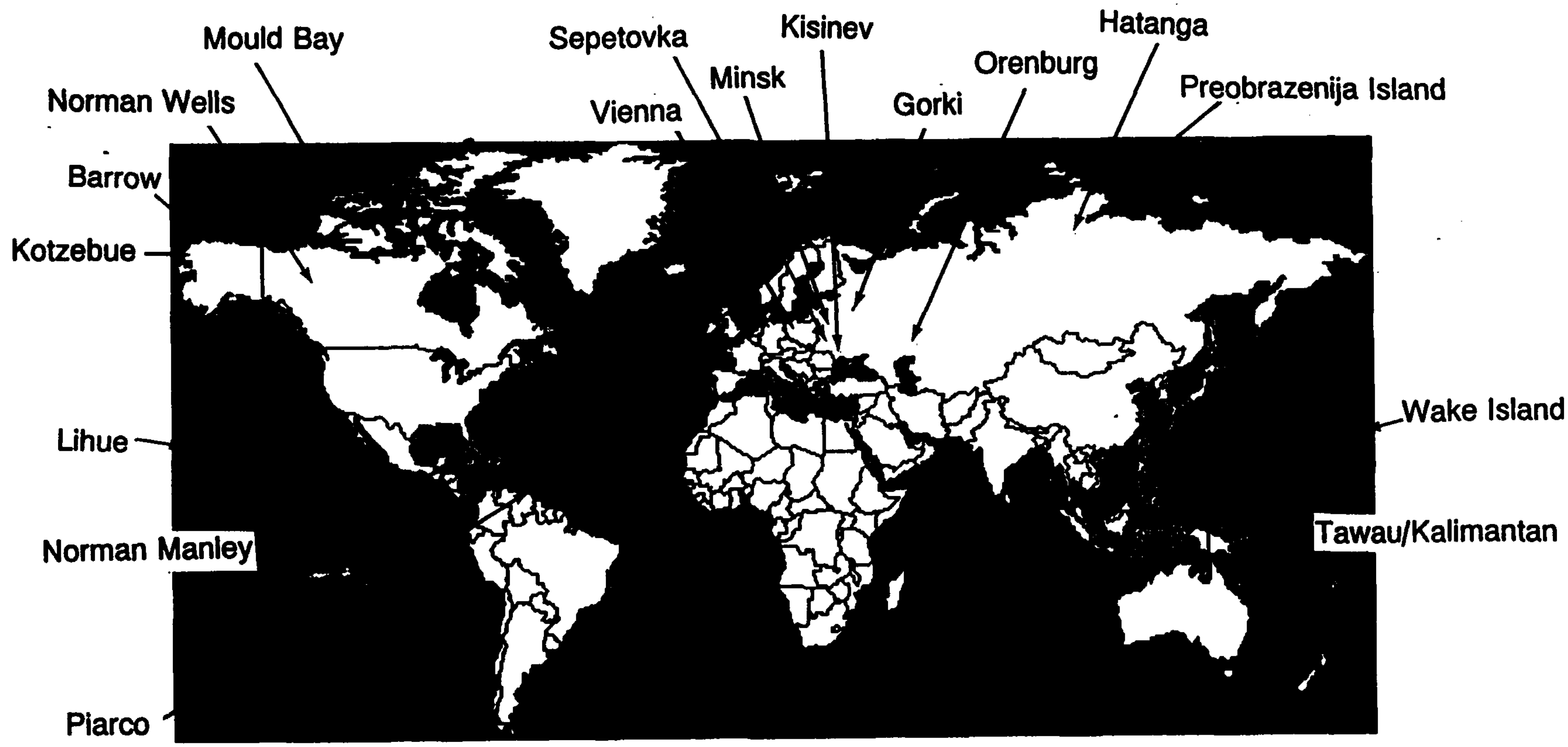


Figure 2. Upper-Air Stations Selected to Represent "Ground Truth."

**2.5 Requirements and Development.** This study resulted in the determination of the minimum sample size needed at three confidence intervals (99, 95, and 90%). This was accomplished in the following steps:

**STEP 1.** AWS/DOS and USAFETAC/DOS selected the ground-truth upper-air stations shown in Figure 2. None of these were on the "blacklists" of the High Resolution Analysis System (HIRAS) or the European Center for Medium-range Weather Forecasting (ECMWF)--that is, none of them had a known recent history of poor data. They were selected from the Arctic (WMO Blocks 70, 25, and 24), the mid-latitudes (WMO Blocks 9, 10, 11, and 12), and the tropics (WMO Blocks 98 and 48). Selections were made on the basis of high data density. Stations chosen also showed good reporting frequency at 00Z and 12Z from 1 to 15 November 1991, as shown by the number of observations in the USAFETAC upper-air database; there were at least a dozen 00Z and 12Z upper-air soundings for each station.

**STEP 2.** AFGWC denied the selected ground truth observations from the non-production HIRAS cycles from 18 January to 10 February 1992. AFGWC imposes a limit of 100 observations denied in one cycle. This limit (documented in the HIRAS maintenance code) insures no degradation in the analysis. Of the 100 observations, 83 are currently used as being from "blacklisted" stations. This left 17 observations per cycle that could be used for test stations. The following steps were used to run the off-line HIRAS between 18 January and 10 February 1992:

- A parallel, non-production version of HIRAS ran for 72 hours to eliminate any contamination by the stations whose observations were denied. AFGWC started this process on 13 January 1992.

- Enough data was denied (17 observations times 2 cycles a day = 34 observations a day) to ensure that 50 observations from each region could be selected randomly. Denial began 18 January and was terminated on 10 February 1992.

**STEP 3.** AFGWC shipped the 00Z, 06Z, 12Z, and 18Z HIRAS data, HIRAS error fields, and denied observations for 18 January-10 February 1992 on the Global ETAC Operational Network (GEON) to USAFETAC/OL-A for QC and reformatting into the USAFETAC database format.

**STEP 4.** OL-A shipped the HIRAS data (on GEON) to USAFETAC. USAFETAC began receiving data-denied HIRAS and RAOB data from OL-A via GEON on 19 January and stored it out to Direct Access Storage Devices (DASD) to prepare for ASPAM analysis.

**STEP 5.** USAFETAC/SYT analysts randomly selected 50 vertical profiles per region by date and time, for a total of 150 events.

**STEP 6.** USAFETAC/DOS analysts produced a point analysis (PA) for each event using the OIVP option of ASPAM and the data-denied HIRAS fields. Ground-truth profiles were produced by specifying the RAOBVP option of ASPAM, using only the denied RAOB as input. This put the ground truth in the same format as the point analyses.

**STEP 7.** USAFETAC/DOS analysts performed manual quality control on each ASPAM RAOBVP and OIVP they had produced. They then used the Man-Computer Interactive Data Access System (McIDAS) to locate inconsistencies in the data.

**STEP 8.** ASPAM OIVP and RAOBVP ground truth analyses were used to conduct a paired difference statistical analysis to find the required sample size for each region. The analysis also determined the difference means, mean sampling error, and confidence limits in the two ways stated earlier in this chapter; that is:

- Using sampling errors of 1° for temperature and 0.05 $g/m^3$ of the highest RAOBVP and OIVP values (based on customer accuracy requirements stated in the USAFETAC/ECS (now DOS) Point Analysis Accuracy Study, August 1990).

- Inspecting a sample size of 50 used to determine sample size for full test.

## 3. DETERMINING SAMPLE SIZE.

**3.1 Objective.** The appropriate sample size for each of the three regions was determined using the desired confidence interval, standard deviation, and allowable sampling error. We examined the 95% and 99% confidence intervals for the paired differences, allowing sampling errors of 1° C for temperature and 5% for humidity. These sampling errors were based on customer requirements stated in the ASPAM accuracy study conducted by USAFETAC/ECS (now DOS) in 1990. The standard deviation of the differences between the RAOBVP ground truth and the OIVP is based on 59, 52, and 53 sample size differences from arctic/polar, mid-latitude, and moist tropics, respectively.

**3.2 Paired Differences.** The *t*-test can be used to test the null hypothesis that the population mean of OIVP-RAOBVP paired differences is equal to zero (Panofsky and Brier, 1968). Temperature differences and humidity differences were calculated by subtracting OIVP data values from RAOBVP ground truth data values. The mean values of the paired differences were based on random sample sizes given in 3.1. The mean differences at heights from the surface to 100,000 feet (HT_1K_FT) above ground level for temperature (° C), and absolute humidity ($g/m^3$), are given in Appendix A. The standard error of the differences are also given.

The tabulated values in Appendix A show moderate skewness for a number of temperature differences except near the surface and at levels near the tropopause (100,000 feet). Kurtosis values for humidity differences are low in a number of cases; but from 35,000 to 50,000 feet, the observation mean differences are very near zero and kurtosis values are extremely high, indicating deviation from a normal distribution. As the kurtosis value increases, the size of the sample necessary to place confidence in our estimated sample standard deviation increases. See the minimum and maximum columns in Appendix A-3 for humidity at the surface and between the 30,000 to 50,000 foot levels.

According to Law and Kelton (1991), the *t*-test can hold its own against troublesome skewness, especially when we deal with paired differences, assuming that the ground-truth RAOBVP and OIVP distributions are skewed in the same direction (as they are in this test--at least most of the time). If ground truth and OIVP distribution skewness values are frequently in opposite directions, we should use a more conservative technique; see 3.3.

**3.3 Simple Random Samples.** The tabular values in Appendices, C-2, C-3, and C-4 represent the desired sampling size based on an optimum (idealistic) sampling error of 1° C for temperature and a desired sampling error of 5% of the highest RAOBVP humidity value and 5% of the highest OIVP humidity value. The sample sizes in C-5 and C-6 were calculated for two cases: (1) sample mean differences were assumed to be normally distributed, and (2) sample mean differences were assumed to be *not* normally distributed. Because Case 2 uses the conservative Chebyshev's inequality to determine sample size, the resultant large sample sizes can be applied to any type of population other than normal.

## 4. SUMMARY OF RESULTS AND CONCLUSIONS.

**4.1 Selecting the Sample Size.** In computing confidence limits, it is common to select a reasonably normal sample size large enough to be able to make assumptions about a sampling distribution. The problem with gathering a large random sample is that it is not always practical, especially when we consider the amount of time it takes to collect HIRAS data and run ASPAM products. One way to overcome these limitations is to recognize the data distortion in the random sample; that is, inspect the skewness and kurtosis values.

**4.2 Desired Sampling Error.** The skewness and kurtosis values shown in Appendices A-2 through A-7 indicate that temperature and humidity differences do not yield a normal distribution in our test: however, even though the two datasets (such as RAOBVP and OIVP values) might be far from being normally distributed, the distribution of the differences (RAOBVP-OIVP) will be approximately normal (Sachs, 1984). Even so, our inclination is to lean toward relying on the more conservative 95% confidence level for the Chebyshev inequality.

Appendices C-2 and C-4 are useful if we wish to maintain the desired sampling error at 1° C for temperature and 5% of absolute humidity at minimum and maximum standard deviation. In C-2, for example, assuming the minimum standard deviation of 1.5309° C, we need at least 9 to 10 observations to be certain that the 95% normal confidence interval contains the true mean difference. However, we need a sample size of least 45 to 47 observations to be certain that the 95% Chebyshev's confidence interval (non-normal) contains the true mean difference. The minimum required sample size at the 99% confidence levels for 1° C for temperature and 5% humidity (0.168 g/m$^3$) are too large to be practical for the time constraints imposed on this study.

> *Note:* Humidity amounts decrease exponentially in the vertical; therefore, the sampling errors for humidity shown in C-1 through C-4 are significant only from the surface to 300 mb (moist levels). The amount of humidity in the upper troposphere (above 300 mb) is negligible; this study does not attempt to measure sampling errors at these heights.

We looked at errors we would have to tolerate if we use a sample size of 50 for the full baseline study. Appendices C-5 (based on population size for a season) and C-6 (based on a very large population size approaching infinity) show the sampling errors for the sample size of 50 for each region. Note that in C-6 the sampling error for a very large population is very similar to our test using the seasonal population size. This indicates that using a seasonally sized population is sufficient, where "seasonal population" is defined as:

- 6 denied stations/region x 3 months
- 3 months/season x 30 days/month
- 2 observations/day = 1,080

Sampling errors of 2.9, 4.2, and 1.9° C for the arctic, mid-latitude, and moist tropic regions, respectively (shown in C-5 for a sample size of 50), coincide with maximum standard deviation of the mean differences for each region. Note that the sampling errors are within 2° C of the instrument error estimates (MGRCC, Document 353-87), which vary linearly with altitude from 0.4° C at the surface to 1.8° C at 30 kilometers.

**4.3 Resultant Confidence.** No matter what the sample size used, one can correct for data distortion. In order to use a small sample of data drawn from a non-normal distribution (such as the sample size of 50 per region per season used for this study), we must adjust the *t* values in the confidence intervals by using either the skewness and kurtosis values or Chebyshev's inequality. Appendices B-2 through B-7 show that the confidence interval contains zero, indicating that the population mean difference is statistically equal to zero. This is most evident in the 99% confidence limits.

By adjusting the *t* values at the 95% level, the skewness and kurtosis values fall within the range of the *t* values based on Chebyshev's inequality at the 95% confidence level. We therefore determined that using the 95% confidence interval based on Chebyshev's inequality would make reasonable inferences about the population mean differences for the three regions.

**4.4 Conclusions.** A sample of 50 observations is enough for a statistically valid variance study of ASPAM temperature and moisture accuracy, provided the customer can accept the sampling errors given in Appendices C-5 and C-6 (95% confidence assuming Chebyshev's inequality). Sampling errors are based on he minimum and maximum standard deviation for temperature and humidity given in Appendices C-2, C-3, and C-4 for each region. If the length of the confidence interval for the mean differences is not small enough to meet customer requirements, a larger sample size will be necessary. Customer requirements will determine if a sample size of 50 is acceptable for future tests.

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## ACRINABS

| | |
|---|---|
| ASPAM | Atmospheric Slant Path Analysis Model |
| AFGWC | Air Force Global Weather Central |
| ECMWF | European Center for Medium-range Weather Forecasting |
| HIRAS | High Resolution Analysis System |
| IPAM | Improved Point Analysis Model |
| MAX | Maximum |
| mb | Millibar |
| McIDAS | Man Computer Interactive Data Access System |
| MIN | Minimum |
| NUAV | New Upper Air Validator |
| OIVP | Optimum Interpolation Vertical Profile |
| PA | Point Analysis |
| RAOB | Radiosonde Observation |
| RAOBVP | RAOB-based Vertical Profile |
| RTNEPH | Real-time Nephanalysis |
| STD | Standard Deviation |
| SE | Sampling Error |
| USAFETAC | United States Air Force Environmental Technical Applications Center |
| WMO | World Meteorology Organization |

## Appendix A

# MEAN, STANDARD DEVIATION, SKEWNESS, AND KURTOSIS

# ARCTIC/POLAR
# OIVP-RAOBVP TEMPERATURE DIFFERENCES STATISTICS

| HT_1K_FT | N Obs | MEAN OF DIFFERENCES | STANDARD DEVIATION OF DIFFERENCES | MAXIMUM DIFFERENCE BELOW MEAN | MAXIMUM DIFFERENCE ABOVE MEAN | STANDARD ERROR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | 59 | -0.8983051 | 4.6375340 | -21.0000000 | 7.0000000 | 0.6037555 | -1.6140773 | 5.6328858 |
| 2 | 59 | -0.3389831 | 4.2935805 | -12.0000000 | 6.0000000 | 0.5589766 | -1.0020733 | 1.3316117 |
| 3 | 59 | 0.8135593 | 3.2455517 | -7.0000000 | 13.0000000 | 0.4225348 | 0.7460125 | 2.6581147 |
| 4 | 59 | 1.1016949 | 3.0439024 | -6.0000000 | 10.0000000 | 0.3962823 | 0.3252448 | 0.6300992 |
| 5 | 59 | 1.1355932 | 2.3668517 | -5.0000000 | 6.0000000 | 0.3081379 | -0.0946434 | 0.3797406 |
| 6 | 59 | 0.8305085 | 2.2905544 | -5.0000000 | 5.0000000 | 0.2982048 | -0.1232275 | -0.1238945 |
| 7 | 59 | 0.3559322 | 2.2496184 | -6.0000000 | 5.0000000 | 0.2928754 | -0.5472111 | 0.6981250 |
| 8 | 59 | 0.3050847 | 2.0865269 | -5.0000000 | 5.0000000 | 0.2716427 | -0.4926954 | 0.5089764 |
| 10 | 59 | 0 | 2.0844250 | -6.0000000 | 3.0000000 | 0.2713690 | -0.8394599 | 0.4361726 |
| 12 | 59 | -0.0169492 | 1.8050841 | -5.0000000 | 4.0000000 | 0.2350019 | -0.3197849 | 0.5584405 |
| 14 | 59 | -0.0338983 | 1.5309013 | -4.0000000 | 4.0000000 | 0.1993064 | -0.0307100 | 0.9399345 |
| 16 | 59 | -0.0338983 | 1.5753062 | -4.0000000 | 3.0000000 | 0.2050874 | -0.2162075 | -0.27845[illegible]2 |
| 18 | 59 | -0.1864407 | 1.7367695 | -5.0000000 | 4.0000000 | 0.2261080 | -0.2755742 | 0.3516213 |
| 20 | 59 | -0.0677966 | 1.4723241 | -3.0000000 | 4.0000000 | 0.1916803 | -0.0134739 | -0.1265997 |
| 25 | 59 | -0.1186441 | 1.7328942 | -4.0000000 | 5.0000000 | 0.2256036 | 0.1899358 | 0.3898451 |
| 30 | 59 | 0.4745763 | 2.3514921 | -6.0000000 | 5.0000000 | 0.3061382 | -0.3086975 | -0.0094229 |
| 35 | 59 | 0.6440678 | 1.7196903 | -4.0000000 | 6.0000000 | 0.2238846 | 0.3046434 | 1.9614620 |
| 40 | 59 | -0.2203390 | 1.2327121 | -3.0000000 | 3.0000000 | 0.1604854 | 0.0942263 | 0.2326296 |
| 45 | 59 | -0.4067797 | 1.2473233 | -4.0000000 | 3.0000000 | 0.1623877 | 0.1111954 | 0.5705896 |
| 50 | 59 | -0.7288136 | 1.6170483 | -4.0000000 | 3.0000000 | 0.2105218 | -0.0023716 | -0.4955215 |
| 60 | 59 | -0.0509475 | 1.6127053 | -4.0000000 | 4.0000000 | 0.2099563 | -0.0679994 | 0.1666251 |
| 70 | 59 | -0.3728814 | 2.5723886 | -9.0000000 | 7.0000000 | 0.3348965 | -0.4252530 | 2.2434762 |
| 80 | 59 | -1.1355932 | 3.5304470 | -13.0000000 | 7.0000000 | 0.4596251 | -0.7818417 | 2.5713273 |
| 90 | 59 | -1.2711864 | 3.9515624 | -18.0000000 | 9.0000000 | 0.5144496 | -1.5213515 | 5.7897500 |
| 100 | 59 | -0.6271186 | 4.1890593 | -11.0000000 | 14.0000000 | 0.5453691 | 0.5191422 | 1.8409926 |
| SFC | 59 | -3.4406780 | 5.1537438 | -19.0000000 | 6.0000000 | 0.6709603 | -0.6025754 | 0.7713737 |

# ARCTIC/POLAR
# OIVP-RAOBVP ABSOLUTE HUMIDITY DIFFERENCES STATISITCS

| HT_1K_FT | N Obs | MEAN OF DIFFERENCES | STANDARD DEVIATION OF DIFFERENCES | MAXIMUM DIFFERENCE BELOW MEAN | MAXIMUM DIFFERENCE ABOVE MEAN | STANDARD ERROR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | 59 | 0.0224441 | 0.3313587 | -1.1741000 | 1.1390000 | 0.0431392 | 0.1932830 | 4.4188435 |
| 2 | 59 | 0.0110000 | 0.3373403 | -0.9341000 | 1.1730000 | 0.0439180 | 0.1614716 | 2.4796210 |
| 3 | 59 | 0.0586797 | 0.3191245 | -0.6483000 | 1.2130000 | 0.0415465 | 0.8236910 | 2.4080997 |
| 4 | 59 | 0.0763525 | 0.3466425 | -0.7129000 | 1.1356000 | 0.0451290 | 0.8739584 | 1.9831016 |
| 5 | 59 | 0.0061119 | 0.3146265 | -1.1300000 | 0.7498000 | 0.0409609 | -0.8726460 | 2.1165719 |
| 6 | 59 | 0.0163658 | 0.3258250 | -0.9950000 | 0.8905000 | 0.0424188 | 0.1045911 | 1.7759232 |
| 7 | 59 | -0.0101739 | 0.3219873 | -1.1650000 | 0.9596000 | 0.0419192 | -0.4370169 | 2.8954790 |
| 8 | 59 | -0.0337985 | 0.2853434 | -1.1143000 | 0.7685000 | 0.0371485 | -0.7364262 | 3.1396601 |
| 10 | 59 | -0.0638217 | 0.2254849 | -0.8976000 | 0.2877000 | 0.0293556 | -1.2003449 | 2.9852659 |
| 12 | 59 | -0.0542954 | 0.1714451 | -0.5421700 | 0.3724000 | 0.0223202 | -0.6083362 | 2.1277226 |
| 14 | 59 | -0.0148475 | 0.1089915 | -0.3724000 | 0.3782000 | 0.0141895 | 0.5114369 | 3.7314604 |
| 16 | 59 | -0.0144205 | 0.0684667 | -0.1834000 | 0.1938000 | 0.0089136 | 0.6966613 | 1.5953017 |
| 18 | 59 | -0.0177167 | 0.0387574 | -0.0991000 | 0.0703000 | 0.0050458 | 0.1177095 | -0.2046043 |
| 20 | 59 | -0.0171375 | 0.0226853 | -0.0735000 | 0.0304100 | 0.0029534 | -0.1278628 | -0.1384587 |
| 25 | 59 | -0.0084790 | 0.0093518 | -0.0337500 | 0.0180800 | 0.0012175 | 0.0228624 | 0.6139619 |
| 30 | 59 | 0.0022483 | 0.0056117 | -0.000075000 | 0.0403310 | 0.000730576 | 5.7273750 | 37.7915921 |
| 35 | 59 | 0.000384517 | 0.0016443 | -0.000031000 | 0.0109580 | 0.000214067 | 5.3837581 | 31.4757657 |
| 40 | 59 | 0.000013951 | 0.000097570 | -0.000060100 | 0.000742200 | 0.000012703 | 7.4129806 | 56.1895771 |
| 45 | 59 | 1.7220339E-6 | 7.8972293E-6 | -9.5E-6 | 0.000051200 | 1.0281317E-6 | 4.2572581 | 26.6616827 |
| 50 | 59 | 1.7305085E-6 | 6.728715E-6 | -8.4E-6 | 0.000042900 | 8.7603407E-7 | 3.9596259 | 24.0055631 |
| 60 | 59 | -5.542373E-7 | 2.283775E-6 | -6.5E-6 | 5.4E-6 | 2.9732218E-7 | -0.0660484 | 0.3637408 |
| 70 | 59 | -4.661017E-7 | 1.8537576E-6 | -4.8E-6 | 5.2E-6 | 2.4133869E-7 | 0.0492466 | 0.5185946 |
| 80 | 59 | -2.033893E-7 | 1.4311758E-6 | -4.3E-6 | 2.6E-6 | 1.8632322E-7 | -0.5396218 | 0.1124368 |
| 90 | 59 | -3.29322E-7 | 1.8234666E-6 | -4.95E-6 | 4.05E-6 | 2.3739514E-7 | 0.0531573 | 0.6138934 |
| 100 | 59 | -8.769492E-7 | 1.8788937E-6 | -5.93E-6 | 2.97E-6 | 2.4461115E-7 | -0.5677713 | 0.5718254 |
| SFC | 59 | -0.0978041 | 0.3110145 | -1.1288000 | 0.9700000 | 0.0405948 | 0.3219137 | 5.0007525 |

# MID-LATITUDES
# OIVP-ROABVP TEMPERATURE DIFFERENCES STATISTICS

| HT_1K_FT | N Obs | MEAN OF DIFFERENCES | STANDARD DEVIATION OF DIFFERENCES | MAXIMUM DIFFERENCE BELOW MEAN | MAXIMUM DIFFERENCE ABOVE MEAN | STANDARD ERROR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | 52 | 0.3076923 | 1.5785133 | -3.0000000 | 4.0000000 | 0.2189004 | -0.0042336 | -0.2846974 |
| 2 | 52 | 0.1538462 | 1.7420364 | -4.0000000 | 4.0000000 | 0.2415770 | -0.2695552 | 0.1414289 |
| 3 | 52 | 0.0961533 | 1.5997502 | -3.0000000 | 6.0000000 | 0.2218454 | 0.7038192 | 2.3425816 |
| 4 | 52 | 0.2500000 | 1.4669563 | -4.0000000 | 3.0000000 | 0.2034302 | -0.1429206 | 0.3480802 |
| 5 | 52 | 0.0961533 | 1.4452032 | -3.0000000 | 3.0000000 | 0.2004136 | 0.0285572 | -0.6797318 |
| 6 | 52 | 0.0384615 | 1.5713306 | -4.0000000 | 3.0000000 | 0.2179044 | -0.4127719 | 0.4800409 |
| 7 | 52 | -0.0961538 | 1.6119604 | -4.0000000 | 3.0000000 | 0.2235387 | -0.5093695 | -0.1226944 |
| 8 | 52 | -0.0961538 | 1.5874460 | -4.0000000 | 3.0000000 | 0.2201392 | -0.0197934 | -0.3493567 |
| 10 | 52 | -0.0769231 | 1.5319621 | -3.0000000 | 4.0000000 | 0.2124449 | 0.1341090 | -0.1934225 |
| 12 | 52 | -0.3653846 | 1.7038462 | -5.0000000 | 5.0000000 | 0.2362810 | 0.1312252 | 1.8346997 |
| 14 | 52 | -0.3846154 | 1.6348394 | -4.0000000 | 5.0000000 | 0.2267114 | 0.1784506 | 1.6959277 |
| 16 | 52 | -0.1346154 | 2.0677623 | -5.0000000 | 7.0000000 | 0.2867470 | 0.6854779 | 3.5563820 |
| 18 | 52 | 0.0576923 | 1.8529833 | -6.0000000 | 6.0000000 | 0.2511228 | -0.4529865 | 3.1236593 |
| 20 | 52 | 0.0384615 | 1.7145461 | -4.0000000 | 6.0000000 | 0.2377648 | 0.2293956 | 2.5629382 |
| 25 | 52 | 0.1153846 | 2.1250499 | -5.0000000 | 7.0000000 | 0.2946914 | 0.1714825 | 1.0080280 |
| 30 | 52 | 0.4615385 | 2.1370819 | -6.0000000 | 5.0000000 | 0.2963599 | -0.2633528 | 0.6477378 |
| 35 | 52 | 0.4807692 | 1.7655792 | -3.0000000 | 4.0000000 | 0.2448418 | -0.1336718 | -0.1[illegible]148 |
| 40 | 52 | -0.0538462 | 1.4935760 | -4.0000000 | 5.0000000 | 0.2071217 | 0.6591583 | 2.6[illegible]296 |
| 45 | 52 | -0.1153846 | 1.2626434 | -3.0000000 | 4.0000000 | 0.1750971 | 0.6506150 | 1.1629819 |
| 50 | 52 | 0.3846154 | 2.1434245 | -7.0000000 | 9.0000000 | 0.2972395 | 0.5936708 | 5.7934499 |
| 60 | 52 | 1.4230769 | 3.4433577 | -3.0000000 | 15.0000000 | 0.4775078 | 2.6015675 | 8.2347527 |
| 70 | 52 | 1.8076923 | 4.4238146 | -3.0000000 | 21.0000000 | 0.6134727 | 2.4575294 | 7.1907027 |
| 80 | 52 | 1.9423077 | 6.1752620 | -7.0000000 | 24.0000000 | 0.8563548 | 1.5174720 | 2.3662902 |
| 90 | 52 | -0.4230769 | 6.9320120 | -15.0000000 | 22.0000000 | 0.9612971 | 0.5151219 | 1.2572636 |
| 100 | 52 | 1.2307692 | 5.9065115 | -10.0000000 | 18.0000000 | 0.8190858 | 0.4575609 | 0.3432212 |
| SFC | 52 | 0.4615385 | 2.0907034 | -4.0000000 | 6.0000000 | 0.2899284 | 0.3307554 | 0.2750604 |

# MID-LATITUDES
# OIVP-ROABVP ABSOLUTE HUMIDITY DIFFERENCES STATISTICS

| HT_1K_FT | N Obs | MEAN OF DIFFERENCES | STANDARD DEVIATION OF DIFFERENCES | MAXIMUM DIFFERENCE BELOW MEAN | MAXIMUM DIFFERENCE ABOVE MEAN | STANDARD ERROR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | 52 | 0.0065192 | 0.3777283 | -0.9670000 | 0.8160000 | 0.0523815 | 0.0409276 | -0.0022757 |
| 2 | 52 | -0.0061731 | 0.5281851 | -1.9740000 | 1.5340000 | 0.0732461 | -0.6555359 | 3.6402563 |
| 3 | 52 | -0.0179231 | 0.6534892 | -2.4710000 | 1.6800000 | 0.0906226 | -1.1388191 | 4.6390179 |
| 4 | 52 | -0.0319558 | 0.5704158 | -1.9088000 | 1.3260000 | 0.0791024 | -0.7349361 | 1.6834963 |
| 5 | 52 | -0.0206462 | 0.5445603 | -1.7282000 | 0.9160000 | 0.0755169 | -0.6535733 | 0.7154458 |
| 6 | 52 | -0.0540135 | 0.5845816 | -1.4521000 | 1.7970000 | 0.0810669 | 0.1469082 | 1.4914013 |
| 7 | 52 | -0.0170231 | 0.5571596 | -1.4664000 | 1.7310000 | 0.0772640 | 0.2985545 | 1.4017195 |
| 8 | 52 | -0.0540058 | 0.4698811 | -1.0970000 | 1.6950000 | 0.0651608 | 0.8317092 | 3.2138607 |
| 10 | 52 | -0.0717500 | 0.3298113 | -0.8422000 | 1.1050000 | 0.0457366 | 0.8580335 | 2.4753287 |
| 12 | 52 | -0.0751698 | 0.2561050 | -0.5548000 | 0.6570000 | 0.0355154 | 0.6487265 | 0.3045789 |
| 14 | 52 | -0.0324206 | 0.2187779 | -0.5747000 | 0.7614000 | 0.0303390 | 0.8335946 | 2.9224395 |
| 16 | 52 | -0.0176308 | 0.1717969 | -0.4744000 | 0.6721000 | 0.0238239 | 1.2627532 | 4.6581137 |
| 18 | 52 | -0.0160938 | 0.1289070 | -0.3917000 | 0.3295000 | 0.0178762 | 0.5251767 | 2.1329660 |
| 20 | 52 | -0.0150019 | 0.0717878 | -0.1645700 | 0.2233000 | 0.0099552 | 0.9586378 | 1.7740823 |
| 25 | 52 | -0.0079400 | 0.0201219 | -0.0452400 | 0.0618700 | 0.0027904 | 1.2203688 | 1.9173383 |
| 30 | 52 | 0.0063378 | 0.0051620 | -0.000100000 | 0.0181910 | 0.000715836 | 0.8630694 | -0.1216529 |
| 35 | 52 | 0.0016304 | 0.0018997 | -0.000029000 | 0.0103070 | 0.000263440 | 2.2417314 | 7.6466842 |
| 40 | 52 | 0.000254750 | 0.000745626 | -0.000047100 | 0.0046317 | 0.000103400 | 4.4805684 | 23.7290441 |
| 45 | 52 | 0.000093579 | 0.000370435 | -0.000016700 | 0.0022807 | 0.000051370 | 4.7923615 | 25.2666178 |
| 50 | 52 | 0.000022235 | 0.000143485 | -0.000089000 | 0.000957600 | 0.000019898 | 5.9326774 | 37.4503788 |
| 60 | 52 | -3.996154E-6 | 0.000012658 | -0.000086500 | 8.1E-6 | 1.7553381E-6 | -5.6261903 | 36.7131954 |
| 70 | 52 | -1.394231E-6 | 3.4790924E-6 | -0.000011400 | 6.4E-6 | 4.8246633E-7 | -0.0536239 | 0.5771265 |
| 80 | 52 | -1.011538E-6 | 2.6249671E-6 | -6.8E-6 | 4.9E-6 | 3.6401745E-7 | -0.0091025 | -0.6293338 |
| 90 | 52 | -7.569231E-7 | 2.2258786E-6 | -5E-6 | 5.19E-6 | 3.0867352E-7 | 0.4992786 | 0.1637609 |
| 100 | 52 | -1.666346E-6 | 2.1603858E-6 | -5.23E-6 | 8.31E-6 | 2.9959161E-7 | 2.0405321 | 8.3192943 |
| SFC | 52 | 0.1442500 | 0.4655715 | -0.5660000 | 1.5160000 | 0.0645632 | 0.9702477 | 1.1496351 |

# MOIST TROPICS
# OIVP-RAOBVP TEMPERATURE DIFFERENCES STATISTICS

| HT_1K_FT | N Obs | MEAN OF DIFFERENCES | STANDARD DEVIATION OF DIFFERENCES | MAXIMUM DIFFERENCE BELOW MEAN | MAXIMUM DIFFERENCE ABOVE MEAN | STANDARD ERROR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | 53 | -0.2641509 | 1.9821409 | -4.0000000 | 4.0000000 | 0.2722680 | 0.1972942 | -0.0778243 |
| 2 | 53 | -0.7358491 | 2.1586226 | -5.0000000 | 5.0000000 | 0.2965096 | 0.8841832 | 1.0039808 |
| 3 | 53 | -1.4150943 | 3.1527397 | -6.0000000 | 17.0000000 | 0.4330621 | 3.9234805 | 22.3465789 |
| 4 | 53 | -1.7924528 | 2.6483557 | -9.0000000 | 10.0000000 | 0.3637796 | 1.0645402 | 7.6196424 |
| 5 | 53 | -1.5849057 | 2.1522257 | -7.0000000 | 5.0000000 | 0.2956309 | 0.1639131 | 1.3008260 |
| 6 | 53 | -0.3584906 | 3.2171078 | -6.0000000 | 11.0000000 | 0.4419037 | 1.2233836 | 2.8064211 |
| 7 | 53 | -1.2452830 | 2.6231635 | -10.0000000 | 5.0000000 | 0.3603192 | -0.4527594 | 1.8179048 |
| 8 | 53 | -0.6792453 | 2.1453169 | -5.0000000 | 4.0000000 | 0.2948193 | 0.0015024 | 0.1849541 |
| 10 | 53 | -0.0566038 | 1.6573275 | -3.0000000 | 5.0000000 | 0.2276514 | 0.8335742 | [illegible]0580739 |
| 12 | 53 | -0.2264151 | 1.6943516 | -5.0000000 | 4.0000000 | 0.2327371 | -0.2464534 | [illegible]937325 |
| 14 | 53 | -0.5849057 | 1.5245928 | -6.0000000 | 3.0000000 | 0.2094139 | -0.7799739 | 2.4960783 |
| 16 | 53 | -0.4339623 | 1.7041740 | -5.0000000 | 3.0000000 | 0.2340863 | -0.1294529 | 0.0555200 |
| 18 | 53 | -0.3207547 | 1.8163106 | -4.0000000 | 3.0000000 | 0.2494894 | -0.1606846 | -0.5222453 |
| 20 | 53 | -0.6415094 | 1.6183365 | -4.0000000 | 3.0000000 | 0.2222956 | -0.1598855 | -0.1926782 |
| 25 | 53 | -0.9433962 | 1.8125109 | -5.0000000 | 2.0000000 | 0.2489675 | -0.4699438 | -0.2625187 |
| 30 | 53 | 0.0943396 | 2.1949606 | -8.0000000 | 4.0000000 | 0.3015010 | -0.6462241 | 2.2479756 |
| 35 | 53 | 0.0377358 | 2.2097882 | -7.0000000 | 5.0000000 | 0.3035378 | -0.5829279 | 1.8255494 |
| 40 | 53 | 0.5981132 | 2.6134630 | -10.0000000 | 7.0000000 | 0.3589867 | -1.1541462 | 4.7083167 |
| 45 | 53 | 0.7735849 | 2.4229790 | -7.0000000 | 6.0000000 | 0.3328218 | -0.6940654 | 1.8351929 |
| 50 | 53 | 0.2830189 | 2.4836183 | -9.0000000 | 4.0000000 | 0.3411512 | -1.6756973 | 4.1051855 |
| 60 | 53 | -1.6792453 | 1.9587399 | -8.0000000 | 2.0000000 | 0.2690911 | -0.4220820 | 0.6310177 |
| 70 | 53 | 1.3962264 | 2.5820357 | -5.0000000 | 9.0000000 | 0.3546699 | 0.8029316 | 1.8646703 |
| 80 | 53 | 0.3018868 | 1.9273827 | -4.0000000 | 7.0000000 | 0.2647464 | 0.4901309 | 2.5243568 |
| 90 | 53 | -0.2075472 | 2.6772438 | -6.0000000 | 6.0000000 | 0.3677477 | 0.4806740 | 0.0813738 |
| 100 | 53 | -0.5283019 | 3.1780726 | -9.0000000 | 6.0000000 | 0.4365418 | -0.6336729 | 1.0210979 |
| SFC | 53 | -0.2075472 | 2.5218925 | -5.0000000 | 5.0000000 | 0.3464086 | 0.2808413 | -0.6121122 |

# MOIST TROPICS
# OIVP-RAOBVP ABSOLUTE HUMIDITY DIFFERENCES STATISTICS

| HT_1K_FT | N Obs | MEAN OF DIFFERENCES | STANDARD DEVIATION OF DIFFERENCES | MAXIMUM DIFFERENCE BELOW MEAN | MAXIMUM DIFFERENCE ABOVE MEAN | STANDARD ERROR | Skewness | Kurtosis |
|---|---|---|---|---|---|---|---|---|
| 1 | 53 | 0.8317736 | 2.9711318 | -9.2200000 | 6.5130000 | 0.4081163 | -0.8589117 | 1.4213746 |
| 2 | 53 | 0.7797170 | 2.8033951 | -9.4100000 | 5.9700000 | 0.3850759 | -0.9153171 | 2.1349614 |
| 3 | 53 | 0.5504717 | 2.5552402 | -8.1530000 | 8.1200000 | 0.3509892 | -0.3930423 | 2.5099229 |
| 4 | 53 | 0.2349245 | 2.5526795 | -6.8950000 | 5.8960000 | 0.3506375 | -0.7053081 | 0.9375045 |
| 5 | 53 | -0.8343585 | 3.0846596 | -8.8870000 | 4.7480000 | 0.4237106 | -0.5487999 | -0.2356833 |
| 6 | 53 | -1.1353962 | 2.7600713 | -7.7260000 | 5.0730000 | 0.3791249 | -0.0736410 | -0.6868573 |
| 7 | 53 | -1.2939811 | 2.3002090 | -6.8410000 | 2.9150000 | 0.3159580 | -0.0713777 | -0.7176784 |
| 8 | 53 | -1.1902434 | 2.1640781 | -6.0410000 | 3.2310000 | 0.2972590 | -0.0511056 | -0.5334467 |
| 10 | 53 | -0.8475696 | 1.8639918 | -4.7480000 | 3.3610000 | 0.2560370 | 0.3394767 | -0.0612436 |
| 12 | 53 | -0.6421079 | 1.5220766 | -3.7910000 | 2.7640000 | 0.2090733 | 0.0408065 | -0.2537123 |
| 14 | 53 | -0.4292660 | 1.1343917 | -3.2350000 | 2.4620000 | 0.1558207 | -0.0215774 | 0.2444299 |
| 16 | 53 | -0.3396547 | 0.8861089 | -2.3970000 | 2.3140000 | 0.1217164 | 0.0607373 | 0.8449448 |
| 18 | 53 | -0.3449491 | 0.6342740 | -1.9222000 | 0.7235000 | 0.0871242 | -0.6848711 | 0.0193340 |
| 20 | 53 | -0.1713236 | 0.4814061 | -1.2628000 | 1.0010000 | 0.0661262 | -0.1038489 | -0.2277105 |
| 25 | 53 | -0.0615356 | 0.2344373 | -0.5950400 | 0.4495740 | 0.0322024 | -0.1124772 | -0.2901795 |
| 30 | 53 | -0.0289287 | 0.0795764 | -0.2510900 | 0.1128000 | 0.0109307 | -0.6325531 | 0.7912948 |
| 35 | 53 | 0.0279088 | 0.0249734 | 0.000883000 | 0.0937550 | 0.0034304 | 0.8383849 | 0.0844231 |
| 40 | 53 | 0.0085329 | 0.0085573 | -0.000011600 | 0.0441438 | 0.0011754 | 1.5935121 | 4.2544067 |
| 45 | 53 | 0.0033354 | 0.0064451 | -7.9E-6 | 0.0464302 | 0.000885308 | 5.9481308 | 39.9938227 |
| 50 | 53 | 0.0015648 | 0.0066864 | -0.000117000 | 0.0490851 | 0.000918444 | 7.1680239 | 51.8857746 |
| 60 | 53 | -0.000016660 | 0.000042994 | -0.000187700 | 0.000046700 | 5.9056554E-6 | -1.8573172 | 3.9597699 |
| 70 | 53 | -9.622642E-7 | 2.8809872E-6 | -7.9E-6 | 4.7E-6 | 3.9573402E-7 | -0.3372950 | 0.0200764 |
| 80 | 53 | 4.0754717E-7 | 1.6096881E-6 | -2.6E-6 | 4.4E-6 | 2.2110767E-7 | 0.3674809 | 0.1981425 |
| 90 | 53 | 3.6226415E-7 | 1.2509391E-6 | -3.36E-6 | 3.06E-6 | 1.718297E-7 | -0.4024273 | 0.3996088 |
| 100 | 53 | 3.8792453E-7 | 1.2035945E-6 | -4.02E-6 | 2.94E-6 | 1.6532643E-7 | -0.7384928 | 2.8139778 |
| SFC | 53 | 0.2306226 | 3.1763088 | -7.1400000 | 7.7150000 | 0.4362996 | -0.1227556 | -0.0844464 |

# Appendix B

## MEAN DIFFERENCES AND CONFIDENCE LIMITS

## SAMPLING ERROR

# ARCTIC/POLAR
# CONFIDENCE LIMITS FOR
# OIVP-RAOBVP TEMPERATURE DIFFERENCES

| OBS | HT_1K_FT | XBART | UL_99_NT | LL_99_NT | UL_95_NT | LL_95_NT | UL_90_NT | LL_90_NT | UL_99_CT | LL_99_CT | UL_95_CT | LL_95_CT | UL_90_CT | UL_90_CT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | -0.89831 | 0.70708 | -2.50429 | 0.30921 | -2.10582 | 0.10997 | -1.90658 | 5.13925 | -6.9359 | 1.81859 | -3.61520 | 1.03371 | 1.03371 |
| 2 | 2 | -0.33898 | 1.14709 | -1.82505 | 0.77897 | -1.45694 | 0.59451 | -1.27247 | 5.25079 | -5.9297 | 2.17641 | -2.85438 | 1.44974 | 1.44974 |
| 3 | 3 | 0.81356 | 1.93750 | -0.31038 | 1.65863 | -0.03151 | 1.51719 | 0.10793 | 5.03891 | -3.4118 | 2.71497 | -1.08785 | 2.16567 | 2.16567 |
| 4 | 4 | 1.10159 | 2.15581 | 0.04758 | 1.89426 | 0.30913 | 1.76349 | 0.43990 | 5.06452 | -2.8611 | 2.89497 | -0.69158 | 2.36980 | 2.36980 |
| 5 | 5 | 1.13559 | 1.95524 | 0.31595 | 1.75187 | 0.51932 | 1.65018 | 0.62100 | 4.21697 | -1.9458 | 2.52221 | -0.25103 | 2.12163 | 2.12163 |
| 6 | 6 | 0.83051 | 1.62373 | 0.03729 | 1.42692 | 0.23410 | 1.32851 | 0.33251 | 3.81256 | -2.1515 | 2.17243 | -0.51141 | 1.79476 | 1.78476 |
| 7 | 7 | 0.35593 | 1.13499 | -0.42312 | 0.94165 | -0.22982 | 0.84503 | -0.13317 | 3.28459 | -2.5729 | 1.67387 | -0.96201 | 1.29313 | 1.29313 |
| 8 | 8 | 0.30508 | 1.02765 | -0.41748 | 0.84837 | -0.23820 | 0.75873 | -0.14856 | 3.02151 | -2.4113 | 1.52748 | -0.91731 | 1.17434 | 1.17434 |
| 9 | 10 | 0.00000 | 0.72184 | -0.72184 | 0.54274 | -0.54274 | 0.45319 | -0.45319 | 2.71369 | -2.7137 | 1.22116 | -1.22116 | 0.86838 | 0.86838 |
| 10 | 12 | -0.01695 | 0.60816 | -0.64205 | 0.45305 | -0.48695 | 0.37550 | -0.40940 | 2.33307 | -2.3670 | 1.04056 | -1.07444 | 0.73506 | 0.73506 |
| 11 | 14 | -0.03390 | 0.49626 | -0.56405 | 0.36471 | -0.43251 | 0.29894 | -0.36674 | 1.95917 | -2.0270 | 0.86298 | -0.93079 | 0.60388 | 0.60388 |
| 12 | 16 | -0.03390 | 0.51163 | -0.57943 | 0.37629 | -0.44407 | 0.30860 | -0.37639 | 2.01695 | -2.0848 | 0.88900 | -0.95679 | 0.62238 | 0.62238 |
| 13 | 18 | -0.18644 | 0.41501 | -0.78789 | 0.26578 | -0.63866 | 0.19116 | -0.56404 | 2.07454 | -2.4475 | 0.83105 | -1.20393 | 0.53710 | 0.53710 |
| 14 | 20 | -0.06780 | 0.44207 | -0.57767 | 0.31556 | -0.45116 | 0.25231 | -0.38790 | 1.84901 | -1.9846 | 0.79476 | -0.93036 | 0.54558 | 0.54558 |
| 15 | 25 | -0.11865 | 0.48145 | -0.71875 | 0.33256 | -0.56985 | 0.25811 | -0.49540 | 2.13739 | -2.3747 | 0.89657 | -1.13386 | 0.60329 | 0.60329 |
| 16 | 30 | 0.47458 | 1.28890 | -0.33975 | 1.08685 | -0.13770 | 0.98563 | -0.03667 | 3.53596 | -2.5869 | 1.85220 | -0.90305 | 1.45422 | 1.45422 |
| 17 | 35 | 0.64407 | 1.23960 | 0.04853 | 1.09184 | 0.19630 | 1.01796 | 0.27018 | 2.88291 | -1.5949 | 1.65155 | -0.36341 | 1.36050 | 1.36050 |
| 18 | 40 | -0.22034 | 0.20655 | -0.64723 | 0.10063 | -0.54131 | 0.04767 | -0.48835 | 1.38452 | -1.8252 | 0.50185 | -0.94252 | 0.29321 | 0.29321 |
| 19 | 45 | -0.40678 | 0.02517 | -0.83873 | -0.08209 | -0.73155 | -0.13559 | -0.67797 | 1.21710 | -2.0307 | 0.32396 | -1.13752 | 0.11286 | 0.11286 |
| 20 | 50 | -0.72881 | -0.15983 | -1.28890 | -0.30777 | -1.14986 | -0.37724 | -1.08038 | 1.37640 | -2.8340 | 0.21353 | -1.67616 | -0.05514 | -0.05514 |
| 21 | 60 | -0.05085 | 0.50764 | -0.60933 | 0.36907 | -0.47076 | 0.29978 | -0.40147 | 2.04872 | -2.1504 | 0.89396 | -0.99565 | 0.62101 | 0.62101 |
| 22 | 70 | -0.37288 | 0.51794 | -1.26371 | 0.29691 | -1.04267 | 0.18640 | -0.93216 | 2.97608 | -3.7218 | 1.13415 | -1.87992 | 0.69879 | 0.69879 |
| 23 | 80 | -1.13559 | 0.08701 | -2.35820 | -0.21634 | -2.05484 | -0.36802 | -1.90317 | 3.46066 | -5.7319 | 0.93272 | -3.20391 | 0.33521 | 0.33521 |
| 24 | 90 | -1.27119 | 0.09725 | -2.63962 | -0.24229 | -2.30009 | -0.41206 | -2.13032 | 3.87331 | -6.4157 | 1.04384 | -3.58621 | 0.37505 | 0.37505 |
| 25 | 100 | -0.62712 | 0.82356 | -2.07780 | 0.46362 | -1.71786 | 0.28365 | -1.53788 | 4.82657 | -6.0808 | 1.82704 | -3.08128 | 1.11906 | 1.11906 |
| 26 | SFC | -3.44068 | -1.65592 | -5.22543 | -2.09876 | -4.78260 | -2.32017 | -4.56119 | 3.26392 | -10.1503 | -0.42136 | -6.46000 | -1.29361 | -1.29361 |

# ARCTIC/POLAR
# CONFIDENCE LIMITS FOR
# OIVP-RAOBVP ABSOLUTE HUMIDITY DIFFERENCES

| OBS | HT_1K_FT | XBARH | UL_99_NH | LL_99_NH | UL_95_NH | LL_95_NH | UL_90_NH | LL_90_NH |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 2.244497E-02 | 1.371944E-01 | -9.230629E-02 | 1.087225E-01 | -6.383440E-02 | 9.449658E-02 | -4.959845E-02 |
| 2 | 2 | 1.100030E-02 | 1.278218E-01 | -1.058218E-01 | 9.883594E-02 | -7.683594E-02 | 8.434301E-02 | -6.234301E-02 |
| 3 | 3 | 6.857966E-02 | 1.791933E-01 | -4.133397E-02 | 1.517726E-01 | -1.441329E-02 | 1.340623E-01 | -7.029560E-04 |
| 4 | 4 | 7.635254E-02 | 1.963957E-01 | -4.369063E-02 | 1.666106E-01 | -1.390549E-02 | 1.517190E-01 | 9.870991E-04 |
| 5 | 5 | 6.111964E-03 | 1.150579E-01 | -1.028441E-01 | 8.303364E-02 | -7.580991E-02 | 7.451654E-02 | -6.229281E-02 |
| 6 | 6 | 1.696381E-02 | 1.297028E-01 | -9.596520E-02 | 1.017064E-01 | -6.796879E-02 | 8.770821E-02 | -5.397059E-02 |
| 7 | 7 | -1.017390E-02 | 1.013311E-01 | -1.216789E-01 | 7.366446E-02 | -9.401225E-02 | 5.983113E-02 | -8.017893E-02 |
| 8 | 8 | -3.379947E-02 | 6.501665E-02 | -1.326136E-01 | 4.049861E-02 | -1.080956E-01 | 2.823959E-02 | -9.583654E-02 |
| 9 | 10 | -6.382168E-02 | 1.426429E-02 | -1.419076E-01 | -5.110422E-03 | -1.225329E-01 | -1.479778E-02 | -1.129456E-01 |
| 10 | 12 | -5.429541E-02 | 5.076448E-03 | -1.136673E-01 | -9.654915E-03 | -9.893590E-02 | -1.702050E-02 | -9.157022E-02 |
| 11 | 14 | -1.484751E-02 | 2.289652E-02 | -5.259154E-02 | 1.353146E-02 | -4.322648E-02 | 8.848931E-03 | -3.854395E-02 |
| 12 | 16 | -1.442046E-02 | 9.289720E-03 | -3.813064E-02 | 3.406744E-03 | -3.224766E-02 | 4.452556E-04 | -2.930617E-02 |
| 13 | 18 | -1.771571E-02 | -4.274942E-03 | -3.113948E-02 | -7.625155E-03 | -2.790827E-02 | -9.290262E-03 | -2.614316E-02 |
| 14 | 20 | -1.713747E-02 | -9.281515E-03 | -2.499343E-02 | -1.123074E-02 | -2.304421E-02 | -1.220535E-02 | -2.206960E-02 |
| 15 | 25 | -8.478966E-03 | -5.240414E-03 | -1.171752E-02 | -6.043964E-03 | -1.091397E-02 | -6.445740E-03 | -1.051219E-02 |
| 16 | 30 | 2.248339E-03 | 4.191672E-03 | 3.050063E-04 | 3.709491E-03 | 7.871866E-04 | 3.468401E-03 | 1.028277E-03 |
| 17 | 35 | 3.845169E-04 | 9.519357E-04 | -1.849018E-04 | 8.126514E-04 | -4.361747E-05 | 7.420092E-04 | 2.702471E-05 |
| 18 | 40 | 1.395085E-05 | 4.773970E-05 | -1.983801E-05 | 3.335600E-05 | -1.145431E-05 | 3.516415E-05 | -7.262455E-06 |
| 19 | 45 | 1.722034E-06 | 4.456964E-06 | -1.012796E-06 | 3.778297E-06 | -3.342295E-07 | 3.439014E-06 | 5.053994E-09 |
| 20 | 50 | 1.730508E-06 | 4.060679E-06 | -5.996624E-07 | 3.482517E-06 | -2.149967E-08 | 3.193435E-06 | 2.675817E-07 |
| 21 | 60 | -5.542273E-07 | 2.366397E-07 | -1.345114E-06 | 4.040707E-08 | -1.148882E-06 | -5.770925E-08 | -1.050765E-06 |
| 22 | 70 | -4.651017E-07 | 1.758592E-07 | -1.108063E-06 | 1.657568E-08 | -9.487791E-07 | -6.306609E-08 | -8.691373E-07 |
| 23 | 80 | -2.033994E-07 | 2.922299E-07 | -6.990096E-07 | 1.692566E-07 | -5.760363E-07 | 1.077699E-07 | -5.145496E-07 |
| 24 | 90 | -3.293229E-07 | 3.021490E-07 | -9.607931E-07 | 1.454682E-07 | -8.041123E-07 | 6.712784E-08 | -7.257719E-07 |
| 25 | 100 | -8.759492E-07 | -2.252835E-07 | -1.527615E-06 | -3.877269E-07 | -1.366171E-06 | -4.684485E-07 | -1.285450E-06 |
| 26 | SFC | -8.750407E-02 | 2.017909E-02 | -1.957362E-01 | -6.614478E-03 | -1.689937E-01 | -2.001076E-02 | -1.559745E-01 |

| OBS | UL_99_CH | LL_99_CH | UL_95_CH | LL_95_CH | UL_90_CH | LL_90_CH |
|---|---|---|---|---|---|---|
| 1 | 4.538364E-01 | -4.099483E-01 | 2.165706E-01 | -1.716825E-01 | 1.604396E-01 | -1.156015E-01 |
| 2 | 4.501797E-01 | -4.281797E-01 | 2.086309E-01 | -1.866309E-01 | 1.515375E-01 | -1.295375E-01 |
| 3 | 4.841444E-01 | -3.467951E-01 | 2.556338E-01 | -1.182795E-01 | 2.016284E-01 | -6.426907E-02 |
| 4 | 5.276427E-01 | -3.749376E-01 | 2.794331E-01 | -1.267290E-01 | 2.207654E-01 | -6.806030E-02 |
| 5 | 4.157207E-01 | -4.034970E-01 | 1.904358E-01 | -1.782121E-01 | 1.371867E-01 | -1.249630E-01 |
| 6 | 4.410556E-01 | -4.073192E-01 | 2.077534E-01 | -1.740158E-01 | 1.526090E-01 | -1.188714E-01 |
| 7 | 4.090179E-01 | -4.293657E-01 | 1.784624E-01 | -1.988102E-01 | 1.239675E-01 | -1.443153E-01 |
| 8 | 3.376870E-01 | -4.052839E-01 | 1.333700E-01 | -2.009669E-01 | 8.507686E-02 | -1.526738E-01 |
| 9 | 2.297346E-01 | -3.573780E-01 | 6.827865E-02 | -1.959220E-01 | 3.011533E-02 | -1.577597E-01 |
| 10 | 1.589071E-01 | -2.774977E-01 | 4.614570E-02 | -1.547365E-01 | 1.712938E-02 | -1.257202E-01 |
| 11 | 1.270473E-01 | -1.567424E-01 | 4.900517E-02 | -7.870019E-02 | 3.055594E-02 | -6.025386E-02 |
| 12 | 7.471555E-02 | -1.035565E-01 | 2.569075E-02 | -5.453166E-02 | 1.410304E-02 | -4.294393E-02 |
| 13 | 3.274107E-02 | -6.617449E-02 | 4.989291E-03 | -4.042271E-02 | -1.570221E-03 | -3.386320E-02 |
| 14 | 1.239621E-02 | -4.667116E-02 | -3.947317E-03 | -3.042763E-02 | -7.686676E-03 | -2.658825E-02 |
| 15 | 3.696043E-03 | -2.065398E-02 | -3.000212E-03 | -1.395772E-02 | -4.582963E-03 | -1.237497E-02 |
| 16 | 9.554101E-03 | -5.057423E-03 | 5.539932E-03 | -1.039254E-03 | 4.586193E-03 | -9.950487E-05 |
| 17 | 2.525185E-03 | -1.756155E-03 | 1.347819E-03 | -5.737855E-04 | 1.069532E-03 | -3.004981E-04 |
| 18 | 1.409756E-04 | -1.130749E-04 | 7.111244E-05 | -4.321075E-05 | 5.459909E-05 | -2.669740E-05 |
| 19 | 1.200335E-05 | -8.559283E-06 | 6.348626E-06 | -2.904559E-06 | 5.012055E-06 | -1.567987E-06 |
| 20 | 1.049055E-05 | -7.029532E-06 | 5.672527E-06 | -2.211510E-06 | 4.533722E-06 | -1.072705E-06 |
| 21 | 2.419958E-06 | -3.527459E-06 | 7.937125E-07 | -1.892187E-06 | 3.971937E-07 | -1.505668E-06 |
| 22 | 1.947235E-06 | -2.879489E-06 | 5.199224E-07 | -1.552126E-06 | 3.061821E-07 | -1.238385E-06 |
| 23 | 1.559842E-06 | -2.060622E-06 | 6.350647E-07 | -1.041844E-06 | 3.928445E-07 | -7.996241E-07 |
| 24 | 2.046479E-06 | -2.703273E-06 | 7.389561E-07 | -1.397600E-06 | 4.303424E-07 | -1.088996E-06 |
| 25 | 1.569152E-06 | -3.323061E-06 | 2.238010E-07 | -1.977699E-06 | -9.419347E-08 | -1.659705E-06 |
| 26 | 3.181439E-01 | -4.927520E-01 | 9.487251E-02 | -2.704305E-01 | 4.209924E-02 | -2.177074E-01 |

# MID-LATITUDES
# CONFIDENCE LIMITS FOR
# OIVP-RAOBVP TEMPERATURE DIFFERENCES

| OBS | HT_1K_FT | XBART | UL_99_NT | LL_99_NT | UL_95_NT | LL_95_NT | UL_90_NT | LL_90_NT | UL_99_CT | LL_99_CT | UL_95_CT | LL_95_CT | UL_90_CT | UL_90_CT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0.30769 | 0.89391 | -0.27852 | 0.74724 | -0.13186 | 0.67457 | -0.05918 | 2.4967 | -1.8813 | 1.29274 | -0.67736 | 1.00817 | 1.00817 |
| 2 | 2 | 0.15385 | 0.80779 | -0.49310 | 0.63893 | -0.33124 | 0.55873 | -0.25104 | 2.5676 | -2.2619 | 1.24094 | -0.93325 | 0.92699 | 0.92699 |
| 3 | 3 | 0.07615 | 0.59026 | -0.49775 | 0.54162 | -0.34731 | 0.46747 | -0.27566 | 2.3146 | -2.1223 | 1.09446 | -0.90215 | 0.80606 | 0.80606 |
| 4 | 4 | 0.25000 | 0.79479 | -0.27479 | 0.65849 | -0.15849 | 0.59095 | -0.09095 | 2.2843 | -1.7843 | 1.16544 | -0.66544 | 0.90098 | 0.90098 |
| 5 | 5 | 0.09615 | 0.63286 | -0.44055 | 0.49856 | -0.30626 | 0.43205 | -0.23974 | 2.1003 | -1.9030 | 0.99802 | -0.80571 | 0.73748 | 0.73748 |
| 6 | 6 | 0.03846 | 0.62201 | -0.54509 | 0.47601 | -0.39909 | 0.40367 | -0.32675 | 2.2175 | -2.1426 | 1.01903 | -0.94211 | 0.73576 | 0.73576 |
| 7 | 7 | -0.09615 | 0.50248 | -0.69479 | 0.35271 | -0.54502 | 0.27850 | -0.47080 | 2.1392 | -2.3315 | 0.90977 | -1.10208 | 0.61917 | 0.61917 |
| 8 | 8 | -0.09615 | 0.49339 | -0.68569 | 0.34589 | -0.53819 | 0.27220 | -0.46511 | 2.1052 | -2.2975 | 0.89447 | -1.08678 | 0.60829 | 0.60829 |
| 9 | 10 | -0.07692 | 0.49200 | -0.64585 | 0.34967 | -0.50351 | 0.27913 | -0.43298 | 2.0475 | -2.2014 | 0.87908 | -1.03293 | 0.60290 | 0.60290 |
| 10 | 12 | -0.36538 | 0.26738 | -0.99815 | 0.10907 | -0.83984 | 0.03062 | -0.76139 | 1.9974 | -2.7252 | 0.69738 | -1.42965 | 0.39071 | 0.39071 |
| 11 | 14 | -0.33462 | 0.32252 | -0.99175 | 0.07062 | -0.83985 | -0.00465 | -0.76458 | 1.8825 | -2.6517 | 0.63559 | -1.40482 | 0.34086 | 0.34086 |
| 12 | 16 | -0.13462 | 0.63329 | -0.90252 | 0.44117 | -0.71040 | 0.34597 | -0.61520 | 2.7029 | -3.0021 | 1.15577 | -1.42498 | 0.78298 | 0.78298 |
| 13 | 18 | 0.05769 | 0.75698 | -0.64159 | 0.58203 | -0.46664 | 0.49533 | -0.37995 | 2.6687 | -2.5535 | 1.23274 | -1.11736 | 0.89329 | 0.89329 |
| 14 | 20 | 0.03846 | 0.67420 | -0.59727 | 0.51589 | -0.43897 | 0.43676 | -0.36003 | 2.4151 | -2.3392 | 1.10849 | -1.03148 | 0.79931 | 0.79931 |
| 15 | 25 | 0.61533 | 1.40457 | -0.17390 | 1.20712 | 0.02354 | 1.10929 | 0.12149 | 3.5623 | -2.3315 | 1.94150 | -0.71073 | 1.55840 | 1.55840 |
| 16 | 30 | 0.46154 | 1.25519 | -0.33211 | 1.05663 | -0.13355 | 0.95824 | -0.03516 | 3.4251 | -2.5021 | 1.79516 | -0.87208 | 1.40989 | 1.40989 |
| 17 | 35 | 0.48077 | 1.13646 | -0.17492 | 0.97241 | -0.01037 | 0.89112 | 0.07041 | 2.9292 | -1.9476 | 1.58256 | -0.62102 | 1.26426 | 1.26426 |
| 18 | 40 | -0.65385 | -0.07917 | -1.22852 | -0.23795 | -1.06975 | -0.30671 | -1.00099 | 1.4174 | -2.7251 | 0.27620 | -1.58589 | 0.00894 | 0.00894 |
| 19 | 45 | -0.11538 | 0.35353 | -0.58429 | 0.23621 | -0.46698 | 0.17808 | -0.40885 | 1.6356 | -1.8664 | 0.57255 | -0.80332 | 0.44493 | 0.44493 |
| 20 | 50 | 0.38462 | 1.18062 | -0.41137 | 0.98147 | -0.21224 | 0.88279 | -0.11355 | 3.3570 | -2.5879 | 1.72219 | -0.95296 | 1.33578 | 1.33578 |
| 21 | 60 | 1.42308 | 2.70164 | 0.14431 | 2.38191 | 0.46424 | 2.22338 | 0.62277 | 6.1982 | -3.3520 | 3.57186 | -0.72571 | 2.95110 | 2.95110 |
| 22 | 70 | 1.80769 | 3.45057 | 0.16481 | 3.03955 | 0.57584 | 2.83587 | 0.77951 | 7.9424 | -4.3270 | 4.56832 | -0.95293 | 3.77080 | 3.77080 |
| 23 | 80 | 1.94231 | 4.23563 | -0.35101 | 3.66187 | 0.22275 | 3.37756 | 0.50706 | 10.5059 | -6.6212 | 5.79590 | -1.91129 | 4.69264 | 4.69264 |
| 24 | 90 | -0.42308 | 2.15128 | -2.99743 | 1.50721 | -2.35336 | 1.18806 | -2.03421 | 9.1899 | -10.0360 | 3.90276 | -4.74891 | 2.65307 | 2.65307 |
| 25 | 100 | 1.23077 | 3.42428 | -0.96274 | 2.87549 | -0.41395 | 2.60356 | -0.14202 | 9.4216 | -6.9601 | 4.91666 | -2.45517 | 3.85184 | 3.85184 |
| 26 | SFC | 0.46154 | 1.23797 | -0.31489 | 1.04371 | -0.12064 | 0.94746 | -0.02438 | 3.3608 | -2.4377 | 1.76622 | -0.84314 | 1.38931 | 1.38931 |

# MID-LATITUDES CONFIDENCE LIMITS FOR OIVP-RAOBVP ABSOLUTE HUMIDITY DIFFERENCES

| OBS | HT_1K_FT | XBAR1 | UL_99_NH | LL_99_NH | UL_95_NH | LL_95_NH | UL_90_NH | LL_90_NH |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 6.519231E-03 | 1.457969E-01 | -1.337584E-01 | 1.117013E-01 | -9.866281E-02 | 9.431061E-02 | -8.127215E-02 |
| 2 | 2 | -6.173077E-03 | 1.899900E-01 | -2.023261E-01 | 1.409051E-01 | -1.532512E-01 | 1.135874E-01 | -1.249335E-01 |
| 3 | 3 | -1.792353E-02 | 2.247644E-01 | -2.606105E-01 | 1.640472E-01 | -1.998933E-01 | 1.339605E-01 | -1.699046E-01 |
| 4 | 4 | -3.195577E-02 | 1.798936E-01 | -2.437921E-01 | 1.268819E-01 | -1.907935E-01 | 1.006199E-01 | -1.645315E-01 |
| 5 | 5 | -2.064615E-02 | 1.815382E-01 | -2.228805E-01 | 1.309918E-01 | -1.722341E-01 | 1.059202E-01 | -1.472125E-01 |
| 6 | 6 | -5.401346E-02 | 1.630537E-01 | -2.711106E-01 | 1.087688E-01 | -2.167959E-01 | 8.185464E-02 | -1.898616E-01 |
| 7 | 7 | -1.702203E-02 | 1.898999E-01 | -2.239360E-01 | 1.381230E-01 | -1.721692E-01 | 1.124714E-01 | -1.465175E-01 |
| 8 | 8 | -5.400577E-02 | 1.204948E-01 | -2.285063E-01 | 7.683708E-02 | -1.848486E-01 | 5.520370E-02 | -1.632152E-01 |
| 9 | 10 | -9.173000E-02 | 3.073260E-02 | -2.142326E-01 | 8.908105E-05 | -1.835591E-01 | -1.509547E-02 | -1.684045E-01 |
| 10 | 12 | -7.516951E-02 | 1.974035E-02 | -1.702300E-01 | -3.854946E-03 | -1.464847E-01 | -1.564605E-02 | -1.346936E-01 |
| 11 | 14 | -3.242059E-02 | 4.882737E-02 | -1.136685E-01 | 2.850021E-02 | -9.334137E-02 | 1.842755E-02 | -8.325881E-02 |
| 12 | 16 | -1.783077E-02 | 4.616975E-02 | -8.143129E-02 | 3.020771E-02 | -6.546925E-02 | 2.229815E-02 | -5.755970E-02 |
| 13 | 18 | -1.609365E-02 | 3.177859E-02 | -6.396628E-02 | 1.990154E-02 | -5.198423E-02 | 1.386664E-02 | -4.605474E-02 |
| 14 | 20 | -1.500192E-02 | 1.165804E-02 | -4.156199E-02 | 4.988073E-03 | -3.499192E-02 | 1.682954E-03 | -3.168690E-02 |
| 15 | 25 | -7.940019E-03 | -4.673049E-04 | -1.541273E-02 | -2.336379E-03 | -1.354315E-02 | -3.203294E-03 | -1.261574E-02 |
| 16 | 30 | 6.337927E-03 | 8.254835E-03 | 4.420819E-03 | 7.775225E-03 | 4.900429E-03 | 7.537567E-03 | 5.139086E-03 |
| 17 | 35 | 1.630445E-03 | 2.335938E-03 | 9.249545E-04 | 2.159433E-03 | 1.101459E-03 | 2.071971E-03 | 1.188921E-03 |
| 18 | 40 | 2.347500E-04 | 5.316546E-04 | -2.215457E-05 | 4.623767E-04 | 4.712327E-05 | 4.280490E-04 | 8.145199E-05 |
| 19 | 45 | 9.857985E-05 | 2.351477E-04 | -3.999021E-05 | 2.017300E-04 | -4.572258E-06 | 1.846751E-04 | 1.248241E-05 |
| 20 | 50 | 2.223462E-05 | 7.552096E-05 | -3.105173E-05 | 6.218943E-05 | -1.772019E-05 | 5.558335E-05 | -1.111412E-05 |
| 21 | 60 | -3.976154E-06 | 7.347755E-07 | -8.697083E-06 | -4.713346E-07 | -7.520973E-06 | -1.054123E-06 | -6.938184E-06 |
| 22 | 70 | -1.394231E-06 | -1.321940E-07 | -2.686267E-06 | -4.254445E-07 | -2.363017E-06 | -5.856223E-07 | -2.202839E-06 |
| 23 | 80 | -1.011533E-05 | -3.669974E-09 | -1.986377E-06 | -2.805914E-07 | -1.742485E-06 | -4.014452E-07 | -1.621632E-06 |
| 24 | 90 | -7.569251E-07 | 6.970542E-08 | -1.583552E-06 | -1.371060E-07 | -1.376740E-06 | -2.395358E-07 | -1.274260E-06 |
| 25 | 100 | -1.656345E-05 | -8.640399E-07 | -2.468652E-06 | -1.064756E-06 | -2.267926E-06 | -1.164231E-06 | -2.168462E-06 |
| 26 | SFC | 1.642500E-01 | 3.371501E-01 | -8.650116E-03 | 2.938928E-01 | 3.460719E-02 | 2.724578E-01 | 5.604216E-02 |

| OBS | UL_99_CH | LL_99_CH | UL_95_CH | LL_95_CH | UL_90_CH | LL_90_CH |
|---|---|---|---|---|---|---|
| 1 | 5.303342E-01 | -5.172957E-01 | 2.422360E-01 | -2.291975E-01 | 1.741400E-01 | -1.611015E-01 |
| 2 | 7.262876E-01 | -7.386340E-01 | 3.234343E-01 | -3.357805E-01 | 2.282144E-01 | -2.405606E-01 |
| 3 | 9.843034E-01 | -9.241495E-01 | 3.899788E-01 | -4.257250E-01 | 2.720694E-01 | -3.079155E-01 |
| 4 | 7.590965E-01 | -8.229802E-01 | 3.240052E-01 | -3.879168E-01 | 2.211720E-01 | -2.850936E-01 |
| 5 | 7.345231E-01 | -7.758154E-01 | 3.191800E-01 | -3.604723E-01 | 2.210090E-01 | -2.623003E-01 |
| 6 | 7.565554E-01 | -8.646823E-01 | 3.107875E-01 | -4.189144E-01 | 2.054006E-01 | -3.134275E-01 |
| 7 | 7.555156E-01 | -7.896530E-01 | 3.306649E-01 | -3.647110E-01 | 2.302217E-01 | -2.642679E-01 |
| 8 | 5.975021E-01 | -7.056136E-01 | 2.392178E-01 | -3.472293E-01 | 1.545087E-01 | -2.625203E-01 |
| 9 | 3.656159E-01 | -5.491159E-01 | 1.140647E-01 | -2.975647E-01 | 5.460710E-02 | -2.381071E-01 |
| 10 | 2.729839E-01 | -4.303235E-01 | 8.464936E-02 | -2.349890E-01 | 3.847937E-02 | -1.888190E-01 |
| 11 | 2.709698E-01 | -3.358110E-01 | 1.041051E-01 | -1.697463E-01 | 6.466435E-02 | -1.295055E-01 |
| 12 | 2.206097E-01 | -2.558702E-01 | 8.957697E-02 | -1.249385E-01 | 5.860595E-02 | -9.386739E-02 |
| 13 | 1.526090E-01 | -1.948557E-01 | 6.434900E-02 | -9.653669E-02 | 4.110996E-02 | -7.329765E-02 |
| 14 | 9.454935E-02 | -1.165537E-01 | 2.979638E-02 | -5.980022E-02 | 1.685464E-02 | -4.685849E-02 |
| 15 | 1.996497E-02 | -3.584511E-02 | 4.616870E-03 | -2.049686E-02 | 9.892984E-04 | -1.686933E-02 |
| 16 | 1.347618E-02 | -8.205295E-04 | 9.559097E-03 | 3.116566E-03 | 8.628501E-03 | 4.047193E-03 |
| 17 | 4.204844E-03 | -1.003751E-03 | 2.819925E-03 | 4.447673E-04 | 2.473453E-03 | 7.974390E-04 |
| 18 | 1.289746E-03 | -7.792477E-04 | 7.200499E-04 | -2.109499E-04 | 5.856292E-04 | -7.612925E-05 |
| 19 | 5.122796E-04 | -4.151217E-04 | 3.297442E-04 | -1.325865E-04 | 2.629631E-04 | -6.580538E-05 |
| 20 | 2.212126E-04 | -1.757435E-04 | 1.117748E-04 | -6.730555E-05 | 8.590762E-05 | -4.143839E-05 |
| 21 | 1.355773E-05 | -2.155003E-05 | 3.903093E-06 | -1.169540E-05 | 1.621385E-06 | -9.613396E-06 |
| 22 | 3.430492E-06 | -5.218364E-06 | 7.768541E-07 | -3.565316E-06 | 1.496514E-07 | -2.938113E-06 |
| 23 | 2.529636E-06 | -4.551713E-06 | 6.265400E-07 | -2.649617E-06 | 1.533174E-07 | -2.176394E-06 |
| 24 | 2.329815E-06 | -3.943561E-06 | 6.321071E-07 | -2.145955E-06 | 2.304332E-07 | -1.744679E-06 |
| 25 | 1.329570E-06 | -4.662262E-06 | -3.181839E-07 | -3.014508E-06 | -7.076530E-07 | -2.625039E-06 |
| 26 | 9.029815E-01 | -4.813815E-01 | 4.547842E-01 | -1.262842E-01 | 3.708521E-01 | -4.235204E-02 |

# MOIST TROPICS
# CONFIDENCE LIMITS FOR
# OIVP-RAOBVP TEMPERATURE DIFFERENCES

| OBS | HT_1K_FT | XBART | UL_99_NT | LL_99_NT | UL_95_NT | LL_95_NT | UL_90_NT | LL_90_NT | UL_99_CT | LL_99_CT | UL_95_CT | LL_95_CT | UL_90_CT | UL_[illegible]_CT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | -0.25415 | 0.46280 | -0.99111 | 0.28039 | -0.80869 | 0.19354 | -0.71884 | 2.45853 | -2.98683 | 0.95106 | -1.48936 | 0.60711 | 0.60711 |
| 2 | 2 | -0.73585 | 0.05582 | -1.52753 | -0.14283 | -1.32857 | -0.24068 | -1.23102 | 2.22925 | -3.70095 | 0.59844 | -2.07014 | 0.21298 | 0.21299 |
| 3 | 3 | -1.41509 | -0.25882 | -2.57137 | -0.54897 | -2.28122 | -0.69138 | -2.13831 | 2.91553 | -5.74572 | 0.59369 | -3.36387 | -0.02930 | -0.02930 |
| 4 | 4 | -1.77465 | -0.82116 | -2.76374 | -1.06489 | -2.52001 | -1.18494 | -2.39996 | 1.84534 | -5.43025 | -0.15544 | -3.42946 | -0.62836 | -0.62836 |
| 5 | 5 | -1.58491 | -0.79557 | -2.37424 | -0.99364 | -2.17617 | -1.09120 | -2.07861 | 1.37140 | -4.54122 | -0.29457 | -2.91524 | -0.63889 | -0.63889 |
| 6 | 6 | -0.35849 | 0.82139 | -1.53837 | 0.52532 | -1.24230 | 0.37949 | -1.09647 | 4.06055 | -4.77753 | 1.63038 | -2.34706 | 1.05560 | 1.05560 |
| 7 | 7 | -1.24528 | -0.28323 | -2.20734 | -0.52464 | -1.96592 | -0.64355 | -1.84702 | 2.35791 | -4.84848 | 0.37615 | -2.86672 | -0.09226 | -0.09226 |
| 8 | 8 | -0.67925 | 0.10792 | -1.46641 | -0.08961 | -1.26888 | -0.18670 | -1.17159 | 2.26895 | -3.62744 | 0.64744 | -2.00593 | 0.26418 | 0.26419 |
| 9 | 10 | -0.05660 | 0.55123 | -0.66443 | 0.39870 | -0.51191 | 0.32357 | -0.43678 | 2.21991 | -2.33312 | 0.96783 | -1.08104 | 0.67188 | 0.67188 |
| 10 | 12 | -0.22642 | 0.39499 | -0.84782 | 0.23906 | -0.69189 | 0.16226 | -0.61509 | 2.10096 | -2.55379 | 0.82090 | -1.27373 | 0.51834 | 0.51834 |
| 11 | 14 | -0.58491 | -0.02576 | -1.14405 | -0.16607 | -1.00374 | -0.23518 | -0.93464 | 1.50928 | -2.67909 | 0.59748 | -1.52729 | 0.08523 | 0.08523 |
| 12 | 16 | -0.43396 | 0.19105 | -1.05897 | 0.03421 | -0.90213 | -0.04304 | -0.82489 | 1.90690 | -2.77483 | 0.61943 | -1.48735 | 0.31511 | 0.31511 |
| 13 | 18 | -0.32075 | 0.34539 | -0.98689 | 0.17822 | -0.81973 | 0.09559 | -0.73740 | 2.17414 | -2.81565 | 0.80195 | -1.44346 | 0.47761 | 0.47761 |
| 14 | 20 | -0.64151 | -0.04798 | -1.23504 | -0.19692 | -1.08610 | -0.27028 | -1.01274 | 1.58145 | -2.86447 | 0.35892 | -1.64194 | 0.06994 | 0.06984 |
| 15 | 25 | -0.94340 | -0.27865 | -1.60814 | -0.44546 | -1.44133 | -0.52762 | -1.35917 | 1.54628 | -3.43307 | 0.17696 | -2.06375 | -0.14670 | -0.14670 |
| 16 | 30 | 0.09434 | 0.89935 | -0.71067 | 0.69734 | -0.50866 | 0.59755 | -0.40917 | 3.10935 | -2.92067 | 1.45109 | -1.26241 | 1.05914 | 1.05914 |
| 17 | 35 | 0.03774 | 0.84818 | -0.77271 | 0.64481 | -0.56934 | 0.54464 | -0.46917 | 3.07311 | -2.99764 | 1.40366 | -1.32818 | 1.00906 | 1.00906 |
| 18 | 40 | 0.69811 | 1.65661 | -0.26038 | 1.41609 | -0.01986 | 1.29762 | 0.09861 | 4.28798 | -2.89175 | 2.31355 | -0.91733 | 1.84687 | 1.84687 |
| 19 | 45 | 0.77358 | 1.66222 | -0.11505 | 1.43923 | 0.10794 | 1.32940 | 0.21777 | 4.10180 | -2.55463 | 2.27128 | [illegible] | 1.83861 | 1.83861 |
| 20 | 50 | 0.28302 | 1.19289 | -0.62785 | 0.96532 | -0.39928 | 0.85274 | -0.28670 | 3.69453 | -3.12849 | 1.81820 | [illegible] | 1.37470 | 1.37470 |
| 21 | 60 | -1.67925 | -0.95080 | -2.39769 | -1.14108 | -2.21741 | -1.22948 | -2.12861 | 1.01157 | -4.37006 | -0.46839 | [illegible] | -0.81819 | -0.81819 |
| 22 | 70 | 1.39623 | 2.34320 | 0.44926 | 2.10557 | 0.68689 | 1.98853 | 0.80393 | 4.94293 | -2.15047 | 2.99224 | [illegible] | 2.53117 | 2.53117 |
| 23 | 80 | 0.30189 | 1.00876 | -0.40499 | 0.83138 | -0.22761 | 0.74401 | -0.14024 | 2.94935 | -2.34558 | 1.49325 | -0.88947 | 1.14908 | 1.14908 |
| 24 | 90 | -0.20755 | 0.77434 | -1.18943 | 0.52795 | -0.94304 | 0.40659 | -0.82169 | 3.46993 | -3.88502 | 1.44732 | -1.86241 | 0.96925 | 0.96925 |
| 25 | 100 | -0.52830 | 0.63726 | -1.69387 | 0.34478 | -1.40139 | 0.20072 | -1.25733 | 3.83712 | -4.89372 | 1.43614 | -2.49274 | 0.86863 | 0.86853 |
| 26 | SFC | -0.20755 | 0.71736 | -1.13246 | 0.48527 | -0.90036 | 0.37096 | -0.78605 | 3.25654 | -3.67163 | 1.35129 | -1.76639 | 0.90096 | 0.90096 |

# MOIST TROPICS
# CONFIDENCE LIMITS FOR
# OIVP-RAOBVP TEMPERATURE DIFFERENCES

| OBS | HT_1K_FT | XBARH | UL_99_NH | LL_99_NH | UL_95_NH | LL_95_NH | UL_90_NH | LL_90_NH |
|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 8.317734E-01 | 1.921444E+00 | -2.578970E-01 | 1.648006E+00 | 1.554090E-02 | 1.913328E+00 | 1.502193E-01 |
| 2 | 2 | 7.797170E-01 | 1.807870E+00 | -2.484357E-01 | 1.549869E+00 | 9.555123E-03 | 1.422794E+00 | 1.366402E-01 |
| 3 | 3 | 5.504717E-01 | 1.487613E+00 | -3.866696E-01 | 1.252450E+00 | -1.515068E-01 | 1.136624E+00 | -3.569032E-02 |
| 4 | 4 | 2.349245E-01 | 1.171127E+00 | -7.012776E-01 | 9.361995E-01 | -4.563504E-01 | 8.204891E-01 | -3.506401E-01 |
| 5 | 5 | -8.343585E-01 | 2.969488E-01 | -1.965666E+00 | 1.306268E-02 | -1.681780E+00 | -1.267618E-01 | -1.541955E+00 |
| 6 | 6 | -1.135295E+00 | -1.231326E-01 | -2.147660E+00 | -3.771453E-01 | -1.893646E+00 | -5.022576E-01 | -1.768535E+00 |
| 7 | 7 | -1.293981E+00 | -4.503733E-01 | -2.137589E+00 | -6.620651E-01 | -1.925897E+00 | -7.663313E-01 | -1.821631E+00 |
| 8 | 9 | -1.180243E+00 | -3.865619E-01 | -1.973925E+00 | -5.857254E-01 | -1.774761E+00 | -6.838209E-01 | -1.676666E+00 |
| 9 | 10 | -8.475595E-01 | -1.639458E-01 | -1.531194E+00 | -3.354919E-01 | -1.359648E+00 | -4.199847E-01 | -1.275155E+00 |
| 10 | 12 | -6.421079E-01 | -8.338222E-02 | -1.200334E+00 | -2.239613E-01 | -1.060255E+00 | -2.929555E-01 | -9.912603E-01 |
| 11 | 14 | -4.292560E-01 | -1.322483E-02 | -8.453073E-01 | -1.176247E-01 | -7.409074E-01 | -1.690455E-01 | -6.894866E-01 |
| 12 | 15 | -3.396547E-01 | -1.467190E-02 | -6.646375E-01 | -9.622189E-02 | -5.830375E-01 | -1.363893E-01 | -5.429211E-01 |
| 13 | 13 | -3.448491E-01 | -1.122274E-01 | -5.774707E-01 | -1.706006E-01 | -5.190975E-01 | -1.993516E-01 | -4.903465E-01 |
| 14 | 20 | -1.713208E-01 | 5.236252E-03 | -3.478778E-01 | -3.906832E-02 | -3.035732E-01 | -6.088997E-02 | -2.817515E-01 |
| 15 | 25 | -6.153558E-02 | 2.444493E-02 | -1.475161E-01 | 2.869296E-03 | -1.259405E-01 | -7.757509E-03 | -1.153137E-01 |
| 16 | 30 | -2.892766E-02 | 2.562092E-04 | -5.811353E-02 | -7.067335E-03 | -5.078999E-02 | -1.067445E-02 | -4.718297E-02 |
| 17 | 35 | 2.790381E-02 | 3.706789E-02 | 1.474974E-02 | 3.476954E-02 | 2.104308E-02 | 3.363752E-02 | 2.218010E-02 |
| 18 | 40 | 6.532279E-03 | 1.167129E-02 | 5.394467E-03 | 1.088375E-02 | 6.182009E-03 | 1.049586E-02 | 6.569902E-03 |
| 19 | 45 | 3.335391E-03 | 5.699162E-03 | 9.716194E-04 | 5.106006E-03 | 1.564775E-03 | 4.813554E-03 | 1.856427E-03 |
| 20 | 50 | 1.564334E-03 | 4.017979E-03 | -8.874107E-04 | 3.401721E-03 | -2.720534E-04 | 3.098635E-03 | 3.103298E-05 |
| 21 | 60 | -1.656038E-05 | -8.922774E-07 | -3.242548E-05 | -4.849067E-06 | -2.947169E-05 | -6.797933E-06 | -2.652282E-05 |
| 22 | 70 | -9.622542E-07 | 9.434569E-08 | -2.018574E-06 | -1.707961E-07 | -1.753732E-06 | -3.013893E-07 | -1.423140E-06 |
| 23 | 80 | 4.075472E-07 | 9.979046E-07 | -1.828103E-07 | 8.497625E-07 | -3.456816E-08 | 7.767970E-07 | 3.829737E-08 |
| 24 | 90 | 3.522542E-07 | 6.210494E-07 | -9.652115E-08 | 7.059236E-07 | 1.860475E-08 | 6.492197E-07 | 7.530855E-08 |
| 25 | 100 | 3.872455E-07 | 8.293461E-07 | -5.349703E-08 | 7.185774E-07 | 5.727168E-08 | 6.640197E-07 | 1.119294E-07 |
| 26 | SFC | 2.306224E-01 | 1.395543E+00 | -9.342972E-01 | 1.103222E+00 | -6.419765E-01 | 9.592429E-01 | -4.979976E-01 |

| OBS | UL_99_CH | LL_99_CH | UL_95_CH | LL_95_CH | UL_90_CH | LL_90_CH |
|---|---|---|---|---|---|---|
| 1 | 4.912937E+00 | -3.249390E+00 | 2.668297E+00 | -1.004750E+00 | 2.137746E+00 | -4.741987E-01 |
| 2 | 4.630476E+00 | -3.071042E+00 | 2.512559E+00 | -9.531247E-01 | 2.011960E+00 | -4.525260E-01 |
| 3 | 4.060364E+00 | -2.959421E+00 | 2.129923E+00 | -1.025980E+00 | 1.573637E+00 | -5.726939E-01 |
| 4 | 3.741279E+00 | -3.271450E+00 | 1.812793E+00 | -1.342944E+00 | 1.356964E+00 | -8.871154E-01 |
| 5 | 3.402747E+00 | -5.071464E+00 | 1.072339E+00 | -2.741056E+00 | 5.215134E-01 | -2.190232E+00 |
| 6 | 2.655853E+00 | -4.926545E+00 | 5.706660E-01 | -2.841458E+00 | 7.780359E-02 | -2.348596E+00 |
| 7 | 1.865599E+00 | -4.453561E+00 | 1.278299E-01 | -2.715792E+00 | -2.829159E-01 | -2.305047E+00 |
| 8 | 1.792346E+00 | -4.152833E+00 | 1.574220E-01 | -2.517909E+00 | -2.290146E-01 | -2.131472E+00 |
| 9 | 1.712820E+00 | -3.407959E+00 | 3.045055E-01 | -1.999745E+00 | -2.824513E-02 | -1.665894E+00 |
| 10 | 1.449625E+00 | -2.732341E+00 | 2.987219E-01 | -1.582938E+00 | 2.692663E-02 | -1.311142E+00 |
| 11 | 1.129941E+00 | -1.997473E+00 | 2.719270E-01 | -1.130459E+00 | 6.936013E-02 | -9.274922E-01 |
| 12 | 9.775074E-01 | -1.556817E+00 | 2.080691E-01 | -8.873786E-01 | 4.983790E-02 | -7.291472E-01 |
| 13 | 5.263932E-01 | -1.216091E+00 | 4.720997E-02 | -7.369081E-01 | -6.605153E-02 | -6.236466E-01 |
| -14 | 4.899414E-01 | -8.325833E-01 | 1.262472E-01 | -4.698887E-01 | 4.028315E-02 | -3.829247E-01 |
| 15 | 2.504896E-01 | -3.835600E-01 | 8.337540E-02 | -2.044466E-01 | 4.151222E-02 | -1.645834E-01 |
| 16 | 8.037777E-02 | -1.382353E-01 | 2.025932E-02 | -7.811664E-02 | 6.049460E-03 | -6.390678E-02 |
| 17 | 6.221246E-02 | -6.394839E-03 | 4.334545E-02 | 1.247217E-02 | 3.888570E-02 | 1.693164E-02 |
| 18 | 2.925723E-02 | -3.221474E-03 | 1.382234E-02 | 3.243420E-03 | 1.229427E-02 | 4.771496E-03 |
| 19 | 1.219847E-02 | -5.517685E-03 | 7.319275E-03 | -6.484935E-04 | 6.163375E-03 | 5.024063E-04 |
| 20 | 1.074927E-02 | -7.619503E-03 | 5.697851E-03 | -2.568163E-03 | 4.503854E-03 | -1.374186E-03 |
| 21 | 4.239616E-05 | -7.571593E-05 | 9.915072E-06 | -4.323583E-05 | 2.237720E-06 | -3.555847E-05 |
| 22 | 2.995076E-06 | -4.919604E-06 | 8.185390E-07 | -2.743067E-06 | 3.040847E-07 | -2.228613E-06 |
| 23 | 7.619624E-06 | -1.803529E-06 | 1.402532E-06 | -5.874373E-07 | 1.115092E-06 | -2.999974E-07 |
| 24 | 2.080561E-06 | -1.356033E-06 | 1.135498E-06 | -4.109695E-07 | 9.121192E-07 | -1.875909E-07 |
| 25 | 2.041189E-06 | -1.265340E-06 | 1.131493E-06 | -3.560444E-07 | 9.169671E-07 | -1.411200E-07 |
| 26 | 4.591616E+00 | -4.132373E+00 | 2.193971E+00 | -1.732725E+00 | 1.626741E+00 | -1.165536E+00 |

# Appendix C

## PILOT STUDY

## MINIMUM AND MAXIMUM SAMPLE SIZES

## PILOT STUDY RESULTS - SAMPLE SIZES

***Based on Temperature Sampling Error of 1° C**

**ARCTIC/POLAR**

LEVEL OF CONFIDENCE

| **Minimum Standard Dev (1.531)** | 95% POPULATION SEASON | 95% POPULATION LARGE | 99% POPULATION SEASON | 99% POPULATION LARGE |
|---|---|---|---|---|
| NORMAL | 9 | 10 | 16 | 17 |
| CHEBYSHEV | 45 | 47 | 193 | 235 |
| **Maximum Standard Dev (5.153)** | | | | |
| NORMAL | 97 | 106 | 160 | 188 |
| CHEBYSHEV | 357 | 533 | 768 | 2660 |

***Based on Humidity Sampling Error of 0.168 g/m³***

**ARCTIC/POLAR**

LEVEL OF CONFIDENCE

| **Minimum Standard Dev (1.823E-6)** | 95% POPULATION SEASON | 95% POPULATION LARGE | 99% POPULATION SEASON | 99% POPULATION LARGE |
|---|---|---|---|---|
| NORMAL | 1 | 1 | 1 | 1 |
| CHEBYSHEV | 1 | 1 | 1 | 1 |
| **Maximum Standard Dev (0.346)** | | | | |
| NORMAL | 17 | 17 | 29 | 30 |
| CHEBYSHEV | 79 | 85 | 303 | 422 |

## PILOT STUDY RESULTS - SAMPLE SIZES
*Based on Temperature Sampling Error of 1° C

### MID-LATITUDE

LEVEL OF CONFIDENCE

| **Minimum Standard Dev (1.263)** | 95% POPULATION SEASON | 95% POPULATION LARGE | 99% POPULATION SEASON | 99% POPULATION LARGE |
|---|---|---|---|---|
| NORMAL | 6 | 7 | 11 | 11 |
| CHEBYSHEV | 31 | 32 | 139 | 159 |
| **Maximum Standard Dev (6.932)** | | | | |
| NORMAL | 165 | 195 | 262 | 346 |
| CHEBYSHEV | 513 | 978 | 883 | 4831 |

*Based on Humidity Sampling Error of 0.2879 g/m$^3$

### MID-LATITUDE

LEVEL OF CONFIDENCE

| **Minimum Standard Dev (2.160E-6)** | 95% POPULATION SEASON | 95% POPULATION LARGE | 99% POPULATION SEASON | 99% POPULATION LARGE |
|---|---|---|---|---|
| NORMAL | 1 | 1 | 1 | 1 |
| HEBYSHEV | 1 | 1 | 1 | 1 |
| **Maximum Standard Dev (0.584)** | | | | |
| NORMAL | 16 | 17 | 29 | 30 |
| CHEBYSHEV | 77 | 83 | 299 | 412 |

PILOT STUDY RESULTS - SAMPLE SIZES
*Based on Temperature Sampling Error of 1° C

**MOIST TROPICS**

LEVEL OF CONFIDENCE

| **Minimum Standard Dev (1.524)** | 95% POPULATION SEASON | 95% POPULATION LARGE | 99% POPULATION SEASON | 99% POPULATION LARGE |
|---|---|---|---|---|
| NORMAL | 9 | 9 | 16 | 17 |
| CHEBYSHEV | 45 | 47 | 191 | 233 |
| **Maximum Standard Dev (3.178)** | | | | |
| NORMAL | 39 | 41 | 68 | 72 |
| CHEBYSHEV | 172 | 204 | 520 | 1010 |

*Based on Humidity Sampling Error of 1.2015 g/m$^3$

**MOIST TROPICS**

LEVEL OF CONFIDENCE

| **Minimum Standard Dev (1.60E-6)** | 95% POPULATION SEASON | 95% POPULATION LARGE | 99% POPULATION SEASON | 99% POPULATION LARGE |
|---|---|---|---|---|
| NORMAL | 1 | 1 | 1 | 1 |
| CHEBYSHEV | 1 | 1 | 1 | 1 |
| **Maximum Standard Dev (3.176)** | | | | |
| NORMAL | 27 | 28 | 48 | 50 |
| CHEBYSHEV | 125 | 142 | 425 | 700 |

## SAMPLING ERRORS AT MAX STANDARD DEVIATION

*based on population=season (1,080 observations) and sample size of 50

**TEMPERATURE (deg C)**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | 1.730 | 1.306 | 6.529 | 2.940 |
| Mid-latitudes (52) | 2.510 | 1.882 | 9.370 | 4.220 |
| Moist Tropics (53) | 1.136 | 0.851 | 4.256 | 1.910 |

**HUMIDITY ($g/m^3$)**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | .117 | 0.088 | 0.439 | .198 |
| Mid-latitudes (52) | .211 | 0.159 | 0.79 | .350 |
| Moist Tropics (53) | 1.136 | 0.851 | 4.256 | 1.910 |

## SAMPLING ERRORS AT MIN STANDARD DEVIATION

*based on population=season (1,080 observations) and sample size of 50

**TEMPERATURE (deg C)**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | 0.516 | 0.388 | 1.940 | 0.872 |
| Mid-latitudes (52) | 0.457 | 0.340 | 1.708 | 0.768 |
| Moist Tropics (53) | 0.545 | 0.408 | 2.042 | 0.919 |

**HUMIDITY ($g/m^3$)**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | 5.0E-7 | 3.0E-7 | 2.2E-6 | 9.0E-7 |
| Mid-latitudes (52) | 7.0E-7 | 5.0E-7 | 2.8E-6 | 1.2E-7 |
| Moist Tropics (53) | 4.0E-7 | 3.0E-7 | 2.0E-6 | 8.0E-7 |

## SAMPLING ERRORS AT MAX STANDARD DEVIATION

*based on large population ( > 500,000) with sample size of 50

**TEMPERATURE (deg C)+**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | 1.780 | 1.342 | 6.710 | 3.020 |
| Mid-latitudes (52) | 2.570 | 1.930 | 9.614 | 4.330 |
| Moist Tropics (53) | 1.165 | 0.873 | 4.365 | 1.960 |

**HUMIDITY (g/m$^3$)**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | .120 | 0.090 | 0.451 | .203 |
| Mid-latitudes (52) | .216 | 0.163 | 0.810 | .364 |
| Moist Tropics (53) | 1.165 | 0.873 | 4.365 | 1.960 |

## SAMPLING ERRORS AT MIN STANDARD DEVIATION

*based on large population( > 500,000) with sample size of 50

**TEMPERATURE (deg C)**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | 0.530 | 0.398 | 1.993 | 0.897 |
| Mid-latitudes (52) | 0.469 | 0.352 | 1.752 | 0.788 |
| Moist Tropics (53) | [illegible]9 | 0.419 | 2.094 | 0.942 |

**HUMIDITY (g/m$^3$)**

| CONFIDENCE LEVEL | | | | |
|---|---|---|---|---|
| REGION size | 99% normal | 95% normal | 99% chebyshev | 95%chebyshev |
| Arctic (59) | [illegible]E-7 | 4.0E-7 | 2.3E-6 | 1.0E-7 |
| Mid-latitudes (52) | 8.0E-7 | 1.3E-6 | 2.9E-6 | 7.0E-7 |
| Moist Tropics (53) | 5.0E-7 | 4.0E-7 | 2.1E-6 | 9.0E-7 |

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| NWS W/OSD, Bldg SSM C-2 East-West Hwy, Silver Spring, MD 20910 | 1 |
| NIST Pubs Production, Rm A635, Admin Bldg, Gaithersburg, MD 20899 | 1 |
| WSO, H & HS Marine Station Wea, MCAS Tustin CA 92710-5000 | 1 |
| DTIC-FDAC, Cameron Station, Alexandria, VA 22304-6145 | 2 |
| AUL/LSE, Maxwell AFB, AL 36112-5564 | 1 |
| AWSTL, Scott AFB, IL 62225-5438 | 35 |